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EDITORIALS AND ANNOTATIONS

INJURIES OF THE SCIATIC NERVE

Injuries of the sciatic nerve are uncommon in civilian practice; consequently few surgeons are able to give a sound opinion on the prospects of recovery after suture, or a severe contusion of the nerve. All of us are likely to be faced sooner or later with one of these problems, for sciatic nerve palsy complicates about one in ten of all hip dislocations, and is even more frequent when there is an associated fracture of the posterior rim of the acetabulum. The two authoritative papers by Clawson and Seddon, which appear in this issue of the Journal, will repay careful study, especially the one on the late consequences of sciatic nerve injury which is based on a study of no fewer than 329 patients followed for three to eighteen years after injury.

In their first paper the authors analyse the results of repair of the sciatic nerve and its branches. They confirm the observations of Platt and Bristow (1924), and the Medical Research Council Report (1954), that useful recovery of motor power cannot be expected in the long flexors of the toes or intrinsic muscles of the foot after suture of the sciatic nerve at any level. It is true that the severe intraneural scarring and the delay in suture which is often unavoidable in gunshot wounds had an adverse influence on recovery, and that somewhat better results might be expected in the occasional clean wound encountered in civilian life. It is also evident that sensation in the foot may continue to improve for a longer period after injury than motor power. An important practical point emerges from the study. A gap of up to twelve centimetres in the sciatic nerve after resection of the nerve ends can be successfully sutured without prejudice to the ultimate recovery. There is therefore every inducement to be generous in the trimming of the nerve ends—within the above limit—until healthy nerve bundles are exposed.

One of the most surprising observations in the second paper is how little the functional result is influenced by the quality of the neurological recovery. The factors that particularly affect function are pressure sores and sensory over-response in the foot. Persistent ulceration is more likely to occur when there is a fixed equinovarus deformity; indeed, lack of sensation in the foot did not by itself cause persistent pressure sores though it was an aggravating factor in the presence of a fixed deformity. Since pressure sores are the usual reason for amputation the greatest care must be taken to prevent a fixed deformity by splinting, physiotherapy, and early tendon transfer when muscle imbalance about the foot makes a deformity inevitable. Lambrinudi's operation was not a successful procedure for the correction of drop foot in these patients, possibly because a rigid foot is never wholly satisfactory when sensation is defective.

Sensory over-response is a common and persistent cause of disability in lesions of the medial popliteal and posterior tibial nerves. When suture of these nerves is required one may have to consider whether the risk of a hypersensitive foot may outweigh the possible gain in function from recovery of motor power. The authors have not attempted to answer this difficult question except for lesions of the posterior tibial nerve at the ankle, where they suggest that suture should be performed only in children. The writer supports this view, having had the experience of sectioning a posterior tibial nerve some time after suture to relieve severe hyperaesthesia in the foot. Finally, amputation should never be performed for persistent pain after a sciatic nerve injury: failure is certain and the unfortunate patient becomes even more apprehensive and introspective. ROLAND BARNES

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PLATT, H., and BRISTOW, W. R. (1924): The Remote Results of Operations for Injuries of the Peripheral Nerves. *British Journal of Surgery*, **11**, 535.

A FURTHER REVIEW OF THE RESULTS OF OPERATIONS ON THE HIP JOINT

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This paper is a continuation of a previous review of the results of arthroplasty of the hi (Shepherd 1954). Results of displacement osteotomy, excision of the head and neck of th femur and Batchelor's operation are included.

MATERIAL

In the present study a total of 314 patients have been re-examined between four and five ye rs after the first review. If patients known to have died and patients whose Judet operations ha d failed completely are excluded, this represents a follow-up of 77 per cent. This figure is w ll below that achieved last time. Then follow-ups of 100 per cent and 98 per cent respectively w re obtained in two lists. This time the best result—82 per cent—was shown by the hospital which previously achieved 98 per cent. The results of 222 operations for displacement osteotomy and of seventy for excision of the head and neck of the femur, with or without osteotomy, have been reviewed.

ASSESSMENT

The method of assessment previously described (Shepherd 1954) has been used. To allow for the fact that patients at the time of the second review were five years older than at the time of the first, cases in which restriction of activity was largely due to a disability such as cardiac disease or hemiplegia have been excluded from all analyses in which function is taken into account. A concession to old age has been made in computing " function by performance " by subtracting one, two and three black marks respectively in the age groups sixty-five to sixty-nine, seventy to seventy-four, and seventy-five to eighty. Two methods of grading have been used. The grading " as a hip " is based on the amount of pain, degree of function, and opinion of the patient. It excludes the index of mobility. The grading " as an arthroplasty " includes the index of mobility.

TABLE I

PERCENTAGE FOLLOW-UP RELATED TO GRADE OF RESULT

Grade " as an arthroplasty " in the first review	Patients attending second review	
	Numbers	Percentages
Excellent . . .	29	86
Good	38	79
Fair	53	74
Poor	50	60

VALIDITY OF A LATE REVIEW

Is the 77 per cent follow-up sufficiently representative of the whole to allow useful onclusions to be drawn? From a study of the two reviews of cup arthroplasty it is clear Table I) that the poorer the result recorded at the first review, the less likely was the patient o attend for later follow-up.

To realise the significance of this we must know what relation grading in the first review ears to grading in the second. Table II shows how the results of cup arthroplasty altered uring the period between the two reviews. The category " failed " indicates that another

operation has been performed on the hip. This is not a " revision "; the original operation has been abandoned. For simplicity and also because the grading " as a hip " is comparable to the patient's rather than the surgeon's estimate, the following figures are quoted from the Table showing the grading " as a hip." Of the thirty-eight hips graded " excellent " in the first review only 5 per cent deteriorated to the " poor " or " failed " class. Eighty-two per cent remained " excellent " or " good." Of the thirty-eight graded " poor " 76 per cent remained " poor " and 24 per cent had improved but only as far as the " fair " class. This is, not only did fewer of the patients with " poor " results come up the second time but " poor " results tended to remain " poor " even when movement was not included in the assessment.

It seems that in a follow-up of over five years, unless there has been at least an 80 per cent attendance, the patients having the best results attend in the largest numbers and those with

TABLE II

CUP ARTHROPLASTY. CHANGES IN GRADING BETWEEN THE TWO REVIEWS FOR PATIENTS WHO HAD HAD THEIR OPERATIONS TWO YEARS OR MORE BEFORE THE FIRST REVIEW

Grade in first review (as an arthroplasty)	Number of operations	Grade in second review (*in percentages*)				
		Excellent	Good	Fair	Poor	Failed
Excellent . .	21	34	43	14	—	9
Good . . .	40	2	56	32	10	—
Fair . . .	46	—	22	54	24	—
Poor . . .	44	—	—	18	71	11
Failed . . .	6	—	—	—	—	100
Grade in first review (as a hip)	**Number of patients**	**Grade in second review (*in percentages*)**				
		Excellent	**Good**	**Fair**	**Poor**	**Failed**
Excellent . .	38	58	24	13	—	5
Good . . .	29	14	55	21	10	—
Fair . . .	46	11	20	56	13	—
Poor . . .	38	—	—	24	63	13
Failed . . .	6	—	—	—	—	100

the poorest results attend less well. The picture in the second review is, therefore, more flattering than strictly truthful. However, if it is kept in mind that this is so and that any adverse findings are rather understated, the analyses show much of interest.

RESULTS OF OPERATIONS ON THE HIP

CUP ARTHROPLASTY

Material—The results of 584 cup arthroplasties were studied. Only patients seen at both reviews were included, but the findings at both reviews were considered.

Results—In this review, even more strikingly than in the first survey, operations performed for unilateral hip disease gave the best results, bilateral operations performed for bilateral disease the poorest, and single operations performed for bilateral disease were intermediate.

It is interesting (Table III) that the highest percentage of " failed" cases was shown in the " single hip " type. This is probably explained by the fact that other satisfactory operations—

TABLE III

C. ARTHROPLASTY. SECOND REVIEW. RESULTS RELATED TO AFFECTION OF ONE OR BOTH HIPS AND TO OPERATION ON ONE OR BOTH HIPS. ALL CONDITIONS EXCEPT TUBERCULOSIS

Results in percentages

Bilateral operation					Single operation—bilateral disease					Single operation—unilateral disease				
120 hips					68 hips					106 hips				
Grades " as an arthroplasty "														
cellent	Good	Fair	Poor	Failed	Excellent	Good	Fair	Poor	Failed	Excellent	Good	Fair	Poor	Failed
3	18	36	40	3	6	25	28	32	9	11	36	26	12	15
21			43		31			41		47			27	
Grades " as a hip "														
16	16	38	27	3	22	15	29	25	9	27	22	24	12	15
32			30		37			34		49			27	

TABLE IV

CUP ARTHROPLASTY. RELATION OF RESULTS TO TIME ELAPSED SINCE OPERATION

Both reviews—figures in percentages

Grade	Years since operation										
	½–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	Over 10
" As an arthroplasty "											
Excellent .	6	17	10	14	9	14	10	7	2	9	—
Good . .	19	16	21	35	26	21	21	32	31	21	(36)
Fair . .	40	43	38	31	26	25	33	32	34	28	(18)
Poor . .	33	18	28	20	35	27	31	27	28	42	(46)
Failed . .	2	6	3	—	4	13	5	2	5	—	—
Numbers (hips)	52	95	63	51	23	52	75	71	58	33	11
" As a hip "											
Excellent .	12	23	13	33	31	25	22	27	15	21	(18)
Good . .	15	10	19	20	13	10	13	20	28	28	(27)
Fair . .	38	44	40	31	26	27	33	35	36	21	(18)
Poor . .	33	17	25	16	26	25	27	17	16	30	(37)
Failed . .	2	6	3	—	4	13	5	1	5	—	—
Numbers (hips)	52	95	63	51	23	52	75	71	58	33	11

Note—Percentages bracketed where numbers less than 20.

TABLE V

CUP ARTHROPLASTY. CHANGES IN GRADING BETWEEN THE TWO REVIEWS

Cases in which the disability was mainly due to causes other than the hip have not been included. Operations that had failed at the time of the first review have been omitted as there is no change in the grading.

Grade in first review	Number of hips	Grade in second review (*in percentages*)				
		Excellent	Good	Fair	Poor	Failed
A. Patients first seen ½–2 years after operation						
"As an arthroplasty"						
Excellent	19	(27)	(68)	—	—	(5)
Good	21	5	33	33	24	5
Fair	65	9	25	34	27	5
Poor	34	—	12	29	47	12
"As a hip"						
Excellent	27	70	19	—	7	4
Good	13	(24)	(15)	(38)	(15)	(8)
Fair	66	18	17	37	23	5
Poor	33	—	15	40	33	12
B. Patients seen in the first review 2–4 years after operation						
"As an arthroplasty"						
Excellent	15	(20)	(53)	(20)	—	(7)
Good	31	3	55	32	10	—
Fair	39	—	18	56	26	—
Poor	29	—	—	24	62	14
"As a hip"						
Excellent	27	51	26	19	—	4
Good	22	18	50	23	9	—
Fair	40	10	15	58	15	2
Poor	25	—	—	32	56	12
C. Patients seen in the first review 4–10 years after operation						
"As an arthroplasty"						
Excellent	6	(68)	(17)	—	—	(17)
Good	9	—	(56)	(33)	(11)	—
Fair	7	—	(43)	(43)	(14)	—
Poor	15	—	—	(7)	(86)	(7)
"As a hip"						
Excellent	11	(73)	(18)	—	—	(9)
Good	7	—	(72)	(14)	(14)	—
Fair	7	(14)	(43)	(43)	—	—
Poor	12	—	—	(8)	(84)	(8)

Note—Percentages bracketed where numbers less than 20.

arthrodesis for instance—are available for the treatment of a single diseased hip, whereas a patient with bilateral affection presents a more difficult problem. In the case of a poor result after bilateral cup arthroplasty an arthrodesis, or any other operation, might be contra-indicated. This case would then be graded as " poor " at review. A similarly unsatisfactory result in a patient who had a single diseased hip might well be treated by arthrodesis for instance. When reviewed this would result in the grading " failed." " Poor " and " failed " should, therefore, be considered together.

TABLE VI

CUP ARTHROPLASTY. YEARS IN WHICH FAILURE OCCURRED. TWENTY-SIX HIPS

Post-operative periods in years	½–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	Over 9
Number of hips " failed " .	1	6	9	4	4	1	—	1	—	—

TABLE VII

CUP ARTHROPLASTY. SECOND REVIEW. RESULTS RELATED TO PRIMARY CONDITION. PERCENTAGE FOLLOW-UP OF PATIENTS SEEN AT FIRST REVIEW. (291 HIPS)

Condition	Grade as an arthroplasty (*in percentages*)				Number of hips	Percentage of first review
	Excellent	Good	Fair	Poor and failed		
Osteoarthritis* . .	9	27	30	34	176	70
Fracture . . .	—	(70)	(10)	(20)	10	50
Otto pelvis . .	—	(29)	(29)	(42)	7	60
Congenital subluxation	(3)	(21)	(29)	(47)	34	74
Congenital dislocation of hip . . .	(13)	(13)	(20)	(54)	15	70
Infective arthritis .	—	(18)	(36)	(46)	11	63
Rheumatoid arthritis .	—	(28)	(44)	(28)	18	85
Ankylosing spondylitis	—	15	35	50	20	65

* Under " osteoarthritis " are included cases of " idiopathic " arthritis, cases in which there was congenital disproportion, and cases following Perthes' disease and slipped epiphysis.

Note—Percentages bracketed where numbers less than 20.

Alteration in grading over the years is shown in Table IV. Although the " excellent " cases decreased in the later years about one-third remained " excellent " or " good." The period showing the highest percentage of good results, and the lowest percentage of poor ones, was three to four years after operation.

It is worth while considering the alteration in grading between the two reviews in relation to the duration of the original follow-up (Table V). The following conclusions can be drawn regarding the results " as a hip." A " poor " case may improve in the first two to four years but is not likely to do so after four years. An " excellent " result achieved in under two years is likely to remain excellent, whereas one achieved after two to four years has rather less chance of lasting. " Excellent " results which have lasted for four to ten years are likely to remain so. These conclusions are supported by the analysis of the twenty-six " failed " results in relation to their years of failing (Table VI).

Relation of result to condition for which operation was performed—Table VII shows the relation of results to the conditions for which operation was performed and also the percentage of the

TABLE VIII

CUP ARTHROPLASTY. PAIN IN RELATION TO POST-OPERATIVE PERIODS

Figures are for both reviews but exclude cases having a mobility index of less than 10. Amounts of pain are indicated thus: 0=no pain, 1=ignores, 2=makes concessions to, 3=disabling. The "Index" is a statistical calculation which produces one figure in each year group to represent the amount of pain in that period. It is obtained by ignoring the percentage figure for pain 0, and adding together the figure for pain 1 to that for pain 2 multiplied by 5, and to that for pain 3 multiplied by 10. It allows easy comparison.

	Pain				Number of hips	Index
	0	1	2	3		
A. Pain in cases of osteoarthritis from any cause (*in percentages*)						
Before operation	—	6	65	29	323	6·21
Years after operation:						
½–1	13	74	13	—	38	1·39
1–2	10	66	22	2	58	1·96
2–3	21	55	24	—	38	1·75
3–4	(23)	(59)	(12)	(6)	17	1·79
4–5	(18)	(73)	(9)	—	11	1·18
5–6	26	58	16	—	31	1·38
6–7	17	57	26	—	47	1·87
7–8	17	59	24	—	42	1·79
8–9	14	50	36	—	22	2·30
9–10	(21)	(43)	(36)	—	14	2·23
B. Pain in patients with conditions other than osteoarthritis						
Before operation	18	4	35	43	151	6·09
Years after operation:						
½–1	—	(55)	(36)	(9)	11	3·25
1–2	17	58	25	—	24	1·83
2–3	(18)	(55)	(27)	—	11	1·90
3–4	28	44	28	—	25	1·84
4–5	(12·5)	(62·5)	(25)	—	8	1·85
5–6	(11)	(78)	(11)	—	9	1·33
6–7	(37·5)	(37·5)	(25)	—	16	1·63
7–8	(26)	(42)	(32)	—	19	2·02
8–9	(25)	(56)	(19)	—	16	1·51
9–10	(33·3)	(44·4)	(22·2)	—	9	1·54

Note—Percentages bracketed where numbers less than 20.

original patients attending for the second review. The numbers of patients with certain conditions—fracture, Otto pelvis and infective arthritis—are too small to allow conclusions to be drawn. The highest percentage of " excellent " and " good " results " as an arthroplasty " were shown in osteoarthritis. There was a 70 per cent attendance of patients suffering from this condition. The lowest percentage of " poor " results was seen in patients with rheumatoid arthritis, 85 per cent of whom attended. Operations for congenital dislocation of the hip had the highest percentage of " poor " results; those for ankylosing spondylitis (only 65 per cent attended) the next highest; and those for congenital subluxation the next. With regard to results " as a hip " operations for ankylosing spondylitis had the highest " excellent " and " good " results and the fewest " poor." Again the patients with congenital dislocation and subluxation had the worst results.

TABLE IX

CUP ARTHROPLASTY. GADE'S MOBILITY INDEX (UNDER 20 AND OVER 50) RELATED TO TIME ELAPSED SINCE OPERATION, TO SINGLE OR DOUBLE AFFECTION AND SINGLE OR DOUBLE OPERATION. NUMBERS OF HIPS GIVEN

Mobility index	Years after operation											Total number
	½–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	Over 10	
Bilateral operation—231 hips*												
Under 20	1	4	6	6	2	2	7	8	10	11	3	60 (26 per cent)
Over 50	5	12	3	5	2	4	4	1	1	3	1	41 (18 per cent)
Unilateral operation, bilateral disease—129 hips												
Under 20	1	1	1	1	1	3	4	5	2	1	1	21 (16 per cent)
Over 50	8	13	7	3	1	4	4	3	4	—	—	47 (37 per cent)
Unilateral operation, unilateral disease—195 hips												
Under 20	—	—	—	—	—	—	3	2	1	—	—	6 (3 per cent)
Over 50	7	28	15	10	3	6	7	10	2	2	1	91 (47 per cent)

* An odd number because occasionally cases were included in which during the years between the reviews an operation of a different type had been performed on one hip.

Pain—The amount of pain in the various years is shown in Table VIII. Patients with stiff hips having a mobility index of under 10 were excluded because stiffness in itself diminishes pain. The Table shows that in osteoarthritis from any cause the most pain-free year was between four and five years after operation. Later the pain tended to increase. When all the other conditions were taken together the best year was between the fifth and sixth, with a slight increase in pain thereafter. Even so, in the osteoarthritic cases nine of the fourteen patients who had their operations nine to ten years earlier had either no pain or an amount they could ignore. Few reverted to pain comparable in severity to that suffered before operation.

Movement—Gade's mobility index is roughly a percentage of the normal range of active movement in a young adult's hip. Table IX shows the hips with mobility indices below 20 and over 50. The greatest range of movement was in the first one to two years after operation; thereafter there was a fairly steady decline in the range. There was a notable difference between the three types of patient. A mobility index of under 20 was shown in only 6 per

TABLE X

CUP ARTHROPLASTY. INDIVIDUAL MOVEMENTS IN RELATION TO PERIOD OF FOLLOW-UP

Years	Flexion	Abduction	Adduction	Lateral rotation	Medial rotation	Numbers (*hips*)
Hips having half or more of the normal range (*in percentages*)						
½–1	68	42	76	32	2	50
1–2	85	59	83	29	23	91
2–3	72	32	82	33	20	60
3–4	60	40	70	32	4	50
4–5	76	14	90	19	10	20
5–6	66	11	75	32	9	44
6–7	52	15	73	25	10	67
7–8	59	14	63	24	8	71
8–9	48	2	65	22	10	54
9–10	52	9	52	15	—	33
Hips having three-quarters or more of the normal range (*in percentages*)						
½–1	26	8	16	2	2	50
1–2	32	3	32	2	2	91
2–3	30	2	13	5	—	60
3–4	20	4	20	8	2	50
4–5	9	—	14	—	5	20
5–6	20	—	34	—	2	44
6–7	11	2	26	1	5	67
7–8	9	—	16	—	—	71
8–9	7	—	7	2	8	54
9–10	13	—	9	3	—	33
Hips having less than half of the normal range (*in percentages*)						
½–1	—	6	—	6	80	50
1–2	—	3	1	5	57	91
2–3	3	7	5	10	62	60
3–4	—	12	—	4	73	50
4–5	—	10	—	10	70	20
5–6	2	25	5	9	64	44
6–7	1	24	5	9	51	67
7–8	1	20	6	10	62	71
8–9	4	33	7	22	68	54
9–10	13	30	15	24	79	33

cent of patients with only one diseased hip; by 16 per cent of patients with bilateral disease who had one operation; and by 26 per cent of patients who had double hip operations. The percentages for hips with a mobility index over 50 were: 47 per cent for the single hip operation, 37 per cent for patients with bilateral disease who had one operation, and 18 per cent for the patients who had bilateral operations. Relating the grading to the mobility index showed that the results in the single hip operation improved with an increasing range up to a mobility index of 50–60. At 60–70 the results were less good. In bilateral disease with one operation the highest percentage of good results occurred in patients with a mobility index of 30–40 and the lowest percentage of poor results in those with an index of 60–70. In the case of the double hip operations the best results were seen in the fifteen patients with a mobility index of 60–70 but the next highest percentage of good results occurred in those with an index of 20–30. The percentage of poor results was lowest when the index was 10–20 and increased steadily as the mobility index rose to 60. This may be an indication of the importance of

TABLE XI

CUP ARTHROPLASTY. FIXED FLEXION DEFORMITY RELATED TO TIME ELAPSED SINCE OPERATION

(*in percentages*)

Years	Fixed flexion		Number (*hips*)
	10–20 degrees	Over 20 degrees	
½–1	12	4	50
1–2	9	1	91
2–3	14	5	60
3–4	20	10	50
4–5	10	—	21
5–6	14	2	44
6–7	19	4	66
7–8	22	7	71
8–9	19	6	54
9–10	28	15	32

stability in at least one hip. Hips which attained good movement after bilateral operation probably acquired their stability by muscular control. When movement was poor, stability was achieved through stiffness of the joint.

Individual movements—In the analysis of individual movements it is seen (Table X) that flexion had a slight and abduction a marked tendency to decrease with the years. Adduction decreased slightly after five years, but the highest percentage of cases with three-quarters or more of the normal range was found between five and six years. The maintenance of the range of flexion compared to the decrease in the range of abduction is probably a reflection of the greater use that is made of flexion in everyday life.

Fixed deformity—Fixed flexion deformity, least at one to two years after operation, showed an erratic tendency to increase with the years (Table XI). In the first review 31 per cent and in the second 47 per cent of the hips showed some degree of flexion deformity. In few instances did it exceed 20 degrees. Adduction deformity was rare. The explanation may lie in the shortening of the limb on the affected side, which causes abduction at the hip when the patient is standing, walking or kneeling.

Fixed flexion of up to 30 degrees did not adversely affect the grading (Table XII). It is probable that the stiffer the hip the more necessary it is to have some flexion deformity. This may be the reason for the good results shown in the second review by hips with flexion deformity of 20–30 degrees. Of the very few cases which showed any adduction deformity those with over 10 degrees gave " poor " results. In the first review 19 per cent and in the second 23 per cent of hips had some degree of fixed lateral rotation deformity. In the second review

TABLE XII

CUP ARTHROPLASTY. RESULTS (AS A HIP) RELATED TO FIXED DEFORMITY IN BOTH REVIEWS

(in percentages)

No fixed deformity—0; *up to* 10 *degrees of fixed deformity*—1; 10–20 *degrees of fixed deformity*—2; 20–30 *degrees of fixed deformity*—3; 30–40 *degrees of fixed deformity*—4.

Fixed flexion deformity

Grade	First review: Degree of deformity					Second review: Degree of deformity				
	0	1	2	3	4	0	1	2	3	4
Excellent	24 } 37	21 } 44	16 } 24	33 } 50	—	23 } 46	26 } 45	24 } 36	19 } 50	—
Good	13 }	23 }	8 }	17 }	—	23 }	19 }	12 }	31 }	50
Fair	42	29	56	17	50	29	35	42	31	25
Poor	21	27	20	33	50	25	20	22	19	25
Numbers (hips)	193	52	25	6	2	147	69	42	16	4
		65 (31 per cent)					131 (47 per cent)			

Fixed lateral rotation deformity

Grade	First review: Degree of deformity				Second review: Degree of deformity				
	0	1	2	3	0	1	2	3
Excellent	24 } 38	18 } 32	9 } 36	—	23 } 42	27 } 54	23 } 41	—
Good	14 }	14 }	27 }	—	19 }	27 }	18 }	—
Fair	40	42	27	—	34	32	23	—
Poor	22	26	37	—	24	14	36	—
Numbers (hips)	223	38	11	4	212	41	17	4
		53 (19 per cent)				62 (23 per cent)		

the results were slightly better with up to 10 degrees of fixed lateral rotation than with either none or more than 10 degrees. Several patients were slightly steadier in the Trendelenburg test when the weight-bearing limb was in a position of some lateral rotation.

The Trendelenburg test—The Trendelenburg test is a simple measure of stability. Table XIII shows the percentage of cases with a positive Trendelenburg test at various times after operation. Stiff hips, and all hips in which the test was doubtful, were excluded. The five to six year post-operative period showed the lowest percentage of Trendelenburg-positive hips, and after that time the percentage rose. It will be remembered that, after four years, the range of

TABLE XIII

CUP ARTHROPLASTY. INCIDENCE OF A POSITIVE TRENDELENBURG SIGN RELATED TO TIME ELAPSED SINCE OPERATION

Cases with a mobility index of under 6 and those in which the test was "doubtful" have been excluded.

Post-operative time in years	Number of hips	Number Trendelenburg positive	Percentage positive
½–1	34	12	35
1–2	71	25	35
2–3	49	16	32
3–4	47	18	38
4–5	17	4	(24)
5–6	27	3	11
6–7	42	11	26
7–8	35	9	26
8–9	34	15	44
9–10	23	9	40
Over 10	14	6	(42)

Note—Percentages bracketed where numbers less than 20.

TABLE XIV

RELATION OF TRENDELENBURG SIGN TO ABSORPTION OF THE FEMORAL NECK

	No absorption	Definite absorption	Slight absorption
123 hips with a negative sign at the first review			
Remaining negative (112)	72	21	19
Becoming positive (11) .	3	6	2
11 hips with a doubtful sign in the first review			
Becoming negative (9) .	7	2	—
Becoming positive (2) .	1	—	1
32 hips with a positive sign at the first review			
Becoming negative (13) .	10	1	2
Remaining positive (19) .	9	8	2

abduction decreased considerably. These two findings might be related, because the power of the abductor muscles would decrease with ageing and with diminution in the range of abduction.

Another factor contributing to the rise in the incidence of the positive Trendelenburg test is the continuing absorption of the femoral neck and, to a lesser extent, of the acetabulum.

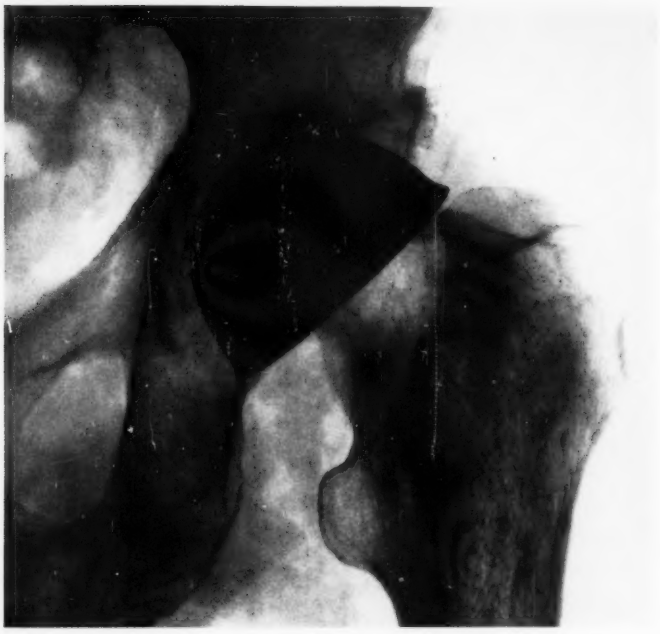

FIG. 1
Radiograph taken five months after cup arthroplasty. Patient aged sixty-five.

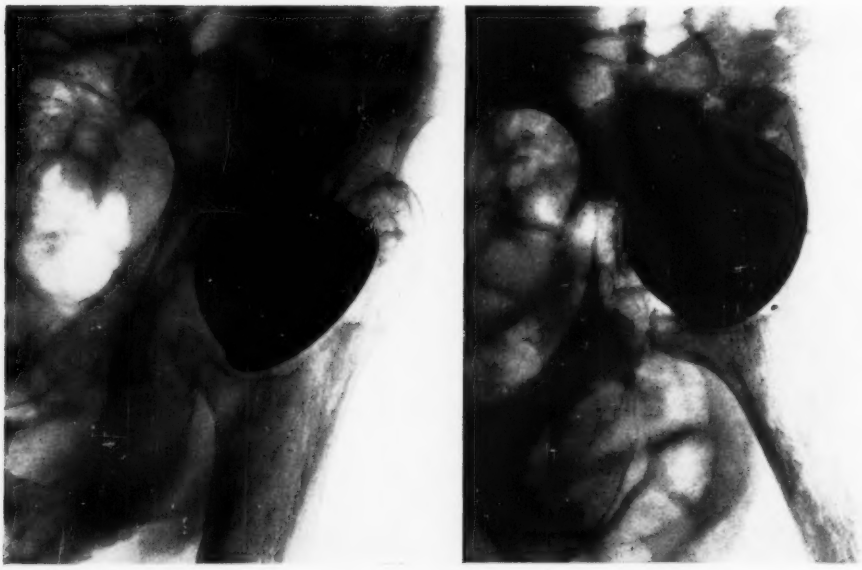

FIG. 2
Radiographs of the same hip taken eight years after operation. Note the extreme absorption of the neck of the femur and the formation of a false acetabulum. Note in the lateral view the crack in the cup and the small piece of detached metal infero-lateral to the cup.

TABLE XV

CUP ARTHROPLASTY. ABSORPTION OF THE NECK OF THE FEMUR AND OF THE ACETABULUM RELATED TO TIME SINCE OPERATION

Absorption of the femoral neck

First review			Second review*				
Years	Numbers (*hips*)	Showing absorption (*percentage*)	Years	Numbers (*hips*)	Showing absorption (*percentage*)	With no absorption (*percentage*)	Insufficient evidence † (*percentage*)
½–1	50	16	5–6	34	47	50	3
1–2	91	26	6–7	63	33	50	17
2–3	60	33	7–8	71	32	55	13
3–4	50	28	8–9	55	27	69	4
4–5	21	33	9–10	29	31	55	14
5–6	9	66					

Absorption of the acetabulum

Second review (absorption increased since first review)

Years	Numbers (*hips*)	Showing absorption (*percentage*)
5–6	34	9
6–7	63	9
7–8	71	11
8–9	55	9
9–10	29	7

Evidence was insufficient in twenty-three hips

* In the second review the cases noted as showing absorption are those in which absorption had *increased* since the first review.

† "Insufficient evidence" indicates that radiographs were not obtainable for comparison or that the views were not comparable.

This is shown, so far as the femoral neck is concerned, when the two reviews are compared and absorption is related to changes in the Trendelenburg sign (Table XIV). The numbers are small because for simplification the case was excluded when the mobility index was below 10 in either review; when the Trendelenburg test was positive or doubtful when the patient was seen a half to one year after operation at the first review; when the positive sign was due to some other factor, such as dislocation; when the radiological evidence was of doubtful value; when the cup had been removed; or when the change in the sign was to "doubtful" or "just negative" or "just positive" in the second review. The hips were divided into three groups: 1) those showing no absorption of the femoral neck in either review or no further absorption in the second review; 2) those showing definite absorption between the reviews; and 3) those showing slight absorption between the reviews.

Table XV shows the percentage of hips with definite radiological absorption of the neck of the femur in both reviews. Further absorption took place in all the year groups and sometimes apparently began after three to four years. Similar figures for absorption of the acetabulum show that this also may continue but in a much smaller number of hips.

TABLE XVI

CUP ARTHROPLASTY. RESULTS RELATED TO TIME ELAPSED SINCE OPERATION AND TO TWO METHODS OF SURGICAL APPROACH

Approach	Years since operation							Grading
	½–2	2–3	3–5	5–6	6–7	7–9	Over 9	
Excellent and good results (*in percentages*)								
Anterior approach without trochanteric transplantation	24	26	44	(44)	34	38	40	As arthroplasty
Posterior approach with trochanteric transplantation	28	(41)	(72)	(53)	29	(55)	(9)	
Anterior approach without trochanteric transplantation	25	33	50	(44)	39	47	48	As hip
Posterior approach with trochanteric transplantation	28	(41)	(72)	(53)	31	(55)	(9)	
Poor results (*in percentages*)								
Anterior approach without trochanteric transplantation	25	19	30	(44)	33	24	40	As arthroplasty
Posterior approach with trochanteric transplantation	37	(17)	(14)	(24)	31	(27)	(55)	
Anterior approach without trochanteric transplantation	23	19	24	(44)	28	15	32	As hip
Posterior approach with trochanteric transplantation	37	(17)	(14)	(18)	26	(27)	(55)	
Numbers throughout (*operations*)								
Anterior approach without trochanteric transplantation	60	27	38	16	21	74	25	
Posterior approach with trochanteric transplantation	43	**12**	**7**	**17**	35	11	**11**	

Note—Very small numbers of cases in bold type. Percentages bracketed where numbers less than 20.

Figures 1 and 2 are illustrative of an extreme case. The first radiograph shows the condition when the patient, a man aged sixty-five, began to bear weight five months after the operation. Figure 2 shows the condition eight years later. At the first review, two to three years after operation, he had an " excellent " result and the Trendelenburg test was negative. At the second review, when the radiograph reproduced in Figure 2 was taken, he still had a " good " result although the Trendelenburg test was positive. He had an occasional twinge of pain and, although he had developed a flexion deformity of 25 degrees and had no abduction at the hip, the mobility index was 24. There was marked absorption of the neck of the femur and of the acetabulum and the cup was cracked. I have seen only one other cracked cup. Both these cups were of stainless steel.

Surgical approach—Table XVI shows the grading in year groups for hips in which the anterior approach without trochanteric transplantation was used and for those in which the posterior or lateral approach with trochanteric transplantation or reposition was employed. At six months to two years and over nine years after operation there were fewer " poor " results when the anterior approach was used. In the intervening years the position was reversed and there

were fewer " poor " cases when the posterior approach was employed. Except in the six to seven year group and over nine years the posterior approach gave a slightly higher proportion of " excellent " and " good " results.

Thirty-six per cent of all the cases in which the method of approach was anterior were Trendelenburg-positive. When the posterior approach had been used 26 per cent were positive.

Comment—Thirty per cent of all cup arthroplasties achieve and maintain good results for ten, and probably more, years. When the operation was performed for a single diseased hip 47 per cent showed good results five or more years after operation but 27 per cent were poor or failed. In the case of bilateral operations the results were worse: only 21 per cent were " good " five years or more after operation, and 43 per cent were " poor." The more quickly an " excellent " result is obtained the more likely it is to persist. An early " poor " result may improve but it is improbable that a patient with a " poor " result at four years will do so.

Movement, especially abduction, tended to decrease in later years, particularly in the case of bilateral operations. Unless stiffness of the joint prevented it, instability was liable to increase. Stability, rather than mobility, is more valuable in bilateral hip disease unless muscular control is particularly good. Pain, although greatly relieved, tended to return to an increasing extent from four to five years onwards after operation. The type of approach, whether anterior or posterior, made little difference to the result.

Cup arthroplasty gave the best results when performed for osteoarthritis. " Excellent " results were not obtained in rheumatoid arthritis but there were few hips that were not improved. Although movement was not well maintained in cases of ankylosing spondylitis the patients who attended the second review had benefited considerably. The least satisfactory results were those of operations for congenital dislocation and subluxation of the hip.

JUDET ARTHROPLASTY

Material—Of the 112 patients with Judet arthroplasties seen at the first review four had died before the second review and fifteen had " failed " results. Of the remaining ninety-three patients forty-nine were seen, of whom forty-seven had had acrylic prostheses and two had metal prostheses.

Results—Only nineteen of the forty-nine hips seen showed no radiological sign of failure such as loosening and downward shifting of the prosthesis parallel to its original line, loosening and tilting of the prosthesis into a more varus position, or absorption of the neck. Exceptionally a prosthesis which had become loose and altered its position maintained the new position without further deterioration, but usually loosening was an indication of impending failure of the operation. Table XVII shows the results in forty-seven cases. In the other two hips the " poor " result was directly attributable to other causes and so they were excluded. Of the nineteen hips showing no signs of failure, eleven were in the four to five post-operative year group, two in the five to six year group and six in the six to seven year group. The analysis of these surviving patients showed results slightly better than those of cup arthroplasty. In only fourteen of the forty-nine hips was the mobility index below 30, and in only two cases, both of ankylosis from infective arthritis, was it below 10. No relation between the result and age, sex, or primary condition could be found.

Comment—The nineteen cases which showed no signs of failing gave very good results from a very early post-operative date and maintained a satisfactory range of movement. If suitable material can be found which will bond with the bone of the femur and be acceptable to the acetabulum a prosthesis to replace the femoral head may have a big place in hip surgery.

DISPLACEMENT OSTEOTOMY

Material—Two hundred and twenty-two hips were examined. In fifty of these some form of internal fixation was used and in the others immobilisation was by plaster or traction. One of the operations in which internal fixation had been employed and three of the others

TABLE XVII

JUDET ARTHROPLASTY

Results in forty-seven patients seen in second review					
Years since operation	Grades "as an arthroplasty" (*numbers of hips*)				Total (*hips*)
	Excellent	Good	Fair	Poor	
4–5	3	5	6	7	21
5–6	—	5	4	3	12
6–7	1	3	7	3	14
"as a hip"					
4–5	4	4	7	6	21
5–6	—	5	4	3	12
6–7	1	3	7	3	14

Results in the nineteen cases which showed no radiological signs of failure					
Years since operation	Results				
		Excellent	Good	Fair	Poor
4–7	"as an arthroplasty"	2	6	6	5
	"as a hip"	4	4	7	4

had failed. These were excluded from the review as recorded information was insufficient. Most of the operations were of the McMurray type. Eleven of the Lorenz type, done mainly for the late effects of congenital dislocation of the hip, were included.

The percentage follow-up was disappointing, partly because the loss of one hospital's operation register during the war-time evacuation prevented the compilation of a full list of patients operated upon there before 1945. Even where lists were obtainable an attendance of only 67 per cent in the post-operative period of two to ten years was secured. The post-operative periods for forty operations ranged from ten to twenty-five years but owing to the unreliability of lists of patients for this period it was impossible to estimate the percentage follow-up for these long-term cases. The analyses of the cases reviewed, and particularly those of the late cases, must, for the reasons already advanced, be taken as flattering to the actual results. It is therefore impossible to give a picture of the late results reliable enough to allow definite comparisons with other hip operations. Some value may however be obtained from one or two general analyses. From a survey of these 218 cases more reliable evidence can be found about the factors that contribute to the quality of the results. The conditions for which operation was performed (Table XVIII) were like those seen in the other operations reviewed here except that there was no case of ankylosing spondylitis. Moreover (Table XIX) there was a fairly large proportion of patients who had a single hip operation performed for unilateral disease. Fifty-nine per cent of the osteotomies with external fixation and 57 per cent of those with internal fixation were of the single hip type, compared with 36 per cent for cup arthroplasty in the second review. Thus the material in this series of displacement osteotomies contains fewer cases of the kind liable to give poor results than does the series of cup arthroplasties.

TABLE XVIII

DISPLACEMENT OSTEOTOMY. RELATION OF RESULTS TO CONDITION FOR WHICH OPERATION WAS PERFORMED

(Eight cases in which the disability was mainly attributable to some other condition have been excluded.) The percentage in each grade is shown except where the total numbers are too small, when the actual numbers are given in brackets.

Diagnosis	Grades								Number of operations
	"as an arthroplasty"				"as a hip"				
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	
Osteoarthritis	7	28	28	37	25	18	35	22	134
Congenital subluxation	7	31	31	31	15	24	46	15	13
Congenital dislocation	13·4	40	33·3	13·4	33·3	20	33·3	13·4	15
Otto pelvis	—	(1)	(1)	(4)	—	(1)	(2)	(3)	6
Recent fracture	—	(1)	(1)	—	—	(1)	(1)	—	2
Old fracture or dislocation	10	32	16	42	37	10	21	32	19
Rheumatoid arthritis	—	(1)	—	(2)	—	(1)	—	(2)	3
Infective arthritis	(1)	(4)	(1)	(5)	(4)	(2)	(3)	(2)	11
Other									7
Numbers in each grade	16	61	52	74	52	37	68	46	210
Percentage in each grade	8	30	26	36	26	18	33	23	

Results—Table XIX shows that the best results were those of operations for a single diseased hip and the poorest those of bilateral operations. Patients with bilateral disease who had one operation obtained intermediate results.

The numbers of cases of Otto pelvis, recent fracture, rheumatoid arthritis and infective arthritis were too small for useful analysis. The grading under the remaining diseases is given in Table XVIII. The best results were obtained when the operation was performed for congenital dislocation of the hip. The next fewest "poor" results were shown in congenital subluxation.

The relation of results to the time elapsed since operation is shown in Table XX. There is not much difference between the results of displacement osteotomy and of cup arthroplasty at similar intervals after operation. The other fact worth noting is the greater discrepancy between the results graded "as an arthroplasty" and "as a hip." This is because stiffness and even bony ankylosis of the hip is liable to occur after osteotomy. Table XXI shows the number of hips—12 per cent of the total—which had ankylosed. In most of these cases operation was done for osteoarthritis. The Table also shows the hips that had a mobility index of under 10. The year groups refer to those in which I saw the patient, not to the time at which the hips stiffened. So far as the records show, this seems to have varied from four and a half months to four years after operation. The range of movement attained after operation may be greater or less than that present before operation. All the patients whose hips became fixed had had, so far as I could determine, some movement previously. On the other hand movement sometimes improved in a most remarkable way. For instance, a woman aged fifty-two had, according to the case notes, only 5 degrees of flexion movement of her hip. The osteotomy produced little, if any, displacement, but when I saw her six or seven years later she had a mobility index of 43 with 35 degrees of flexion.

TABLE XIX

DISPLACEMENT OSTEOTOMY. RESULTS RELATED TO UNILATERAL AND BILATERAL AFFECTION AND TO UNILATERAL AND BILATERAL OPERATION

The figures are in percentages except where the totals are small, when the actual figures are given in brackets

	Displacement osteotomy with external fixation					Displacement osteotomy with internal fixation				
Type—double hip operation										
	Excellent	**Good**	**Fair**	**Poor**	**Number (*hips*)**	**Excellent**	**Good**	**Fair**	**Poor**	**Number (*hips*)**
"As hip" . .	9	18	33	40	32 (19 per cent)	(2)	(1)	(1)	(3)	7 (14 per cent)
"As arthroplasty"	—	27	24	49		(2)	(1)	(1)	(3)	
Type—bilateral disease, single hip operation										
"As hip" . .	8	16	46	30	37 (22 per cent)	(4)	(3)	(4)	(3)	14 (29 per cent)
"As arthroplasty"	3	13	35	49		(1)	(4)	(5)	(4)	
Type—single diseased hip										
"As hip" . .	36	16	32	16	101 (59 per cent)	30	15	22	33	27 (57 per cent)
"As arthroplasty"	12	34	21	33		11	30	22	37	
All types										
"As hip" . .	25	16	36	23	170	29	17	23	31	48
"As arthroplasty"	7	29	24	40		12	27	25	36	

Both varieties—all types

	Excellent	**Good**	**Fair**	**Poor**	**Number (*hips*)**
"As hip" . .	27	16	33	24	218
"As arthroplasty" .	9	28	24	39	

Although there were only forty-nine cases of displacement osteotomy with internal fixation the results may be compared with those of operation without internal fixation. Table XIX shows that the results in the single hip are better without than with internal fixation. The results for the two types of operations done for osteoarthritis are shown in Table XXII.

Relief of pain (Table XXIII) was also better in displacement osteotomy with external fixation. However, the cases with internal fixation showed better mobility than those without (Table XXIV). In the cases of displacement osteotomy with external fixation about half the hips retained a moderate range of movement with a mobility index of over 30, whereas with internal fixation about three-quarters kept this amount.

Observers looking for an explanation of the beneficial results of this operation noted that in many cases there was a bone block to adduction and that it seemed that some weight was transmitted from the displaced shaft of the femur directly to the pelvis. Table XXV shows clearly that better results were obtained when there was more than 10 degrees of adduction

TABLE XX

DISPLACEMENT OSTEOTOMY. RESULTS RELATED TO TIME ELAPSED SINCE OPERATION

Both methods of fixation and all patients except eight in whom the disability was mainly due to another condition

Time since operation		Grading (*percentage*)				Number (*hips*)
		Excellent	Good	Fair	Poor	
To 3 years	"As hip"	29	16	24	31	42
	"As arthroplasty"	12	31	21	36	
3–5 years	"As hip"	31	16	37	16	42
	"As arthroplasty"	5	37	33	25	
5–7 years	"As hip"	22	18	31	29	45
	"As arthroplasty"	7	33	19	41	
7–10 years	"As hip"	22	20	34	24	41
	"As arthroplasty"	12	22	27	39	
Over 10 years	"As hip"	33	15	40	12	40
	"As arthroplasty"	10	23	32	35	

Time since operation	Displacement osteotomy			Cup arthroplasty		
	Excellent and good	Poor	Number (*hips*)	Excellent and good	Poor	Number (*hips*)
5–7 years						
"As hip"	40	29	45	35	35	127
"As arthroplasty"	40	41		33	40	
7–10 years						
"As hip"	42	24	41	46	23	62
"As arthroplasty"	34	39		31	35	

movement than when there was less than 10 degrees, and that a small range of adduction was preferable to none. Pelvic support, as distinguished from a block to adduction, occurred sometimes with the formation of a pseudarthrosis. Twelve hips out of 218 showed this. The pseudarthrosis usually formed between the femoral shaft and the lower border of the acetabulum. Rarely it formed between a deformed head and the upper rim of the acetabulum. When such a pseudarthrosis occurred the result was generally good, there being only one "poor" result among the twelve.

A comparison of the movement of the knee in the two varieties of displacement osteotomy showed that the average range of movement in cases "under two years" with internal fixation was 113 degrees. In the three cases in the same year groups immobilised in plaster it was 100 degrees. In the two to five year groups the average ranges were exactly the same—105 degrees of movement for both types—while for displacement osteotomy with external fixation "over five years" the average range was 101 degrees. It is possible that if the surgeon expected trouble in the knee joint he would have used internal fixation, but so far as late results are concerned the type of fixation used had little effect on the range of movement at the knee.

These analyses suggest that the results of displacement osteotomy were less good when internal fixation was used. In this small series there were three cases of non-union with each

TABLE XXI

DISPLACEMENT OSTEOTOMY. HIPS ANKYLOSED AND WITH LOW MOBILITY INDEX ACCORDING TO THE POST-OPERATIVE PERIOD IN WHICH THEY WERE REVIEWED

Numbers of hips

Year	Ankylosed	Mobility index below 10	Total number in year (*hips*)
2–3	1 (internal fixation)	1	33
3–4	3	4 (1 was internal fixation)	27
4–5	3	1	17
5–6	—	—	19
6–7	3	4	27
7–8	1	—	10
8–9	2	—	14
9–10	3	1	19
10–25	9	3	40
Total	25	14	206

Diagnoses in cases of ankylosis after osteotomy	
Osteoarthritis	18 (fibrous ankylosis in 2)
Infective arthritis	3
Old fracture or dislocation . . .	2
Otto pelvis	1
Congenital subluxation	1

TABLE XXII

RESULTS OF DISPLACEMENT OSTEOTOMY FOR OSTEOARTHRITIS WITH AND WITHOUT INTERNAL FIXATION

	Grades (*in percentages*)							
	"As a hip"				"As an arthroplasty"			
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Displacement osteotomy with external fixation (101 hips) .	28	17	37	18	9	29	27	35
Displacement osteotomy with internal fixation (33 hips) .	18	21	27	34	3	27	30	40

TABLE XXIII

DISPLACEMENT OSTEOTOMY. PAIN AFTER OPERATION

The number of cases in each pain group is shown. Thirty-nine cases with mobility indices below 10 have been excluded. Amounts of pain are indicated thus: 0 = no pain, 1 = ignores, 2 = makes concessions to, 3 = disabling.

	Displacement osteotomy with external fixation				Displacement osteotomy with internal fixation			
	1–8 years after operation				1–8 years after operation			
	Pain				Pain			
	0	1	2	3	0	1	2	3
Number of hips	28	35	9	2	11	23	9	2
	63 (85 per cent)		11 (15 per cent)		34 (75 per cent)		11 (25 per cent)	
	9–25 years after operation							
Number of hips	24	25	8	—				
	49 (86 per cent)		8 (14 per cent)					
	1–25 years after operation							
Number of hips	112 (85 per cent)		19 (15 per cent)					

TABLE XXIV

DISPLACEMENT OSTEOTOMY. MOBILITY INDEX RELATED TO TIME SINCE OPERATION

Years after operation	Mobility index				Total number of hips
	0–9	10–29	30–49	Over 50	
Displacement osteotomy with external fixation (*in percentages*)					
To 3 .	(14)	(22)	(50)	(14)	14
3–5 .	28	24	38	10	29
5–7 .	16	14	49	21	37
7–10 .	19	27	15	39	41
Over 10	27·5	30	27·5	15	39
Displacement osteotomy with internal fixation					
To 3 .	7	29	39	25	28
3–7 .	10	30	45	15	20

Note—Percentages bracketed where numbers less than 20.

TABLE XXV

DISPLACEMENT OSTEOTOMY. RESULTS, " AS A HIP," RELATED TO ADDUCTION MOVEMENT. FORTY-ONE CASES WITH MOBILITY INDICES BELOW 10 HAVE BEEN EXCLUDED

(*In percentages*)

Adduction in degrees	Grades				Total number (*hips*)
	Excellent	Good	Fair	Poor	
None .	(8)	(17)	(25)	(50)	12
	(25)				
To 10 .	22	9	44	25	45
	31				
11–20 .	38	18	23	21	87
	56				
Over 20	31	27	21	21	33
	58				

Note—Percentages bracketed where numbers less than 20.

TABLE XXVI

DISPLACEMENT OSTEOTOMY. RESULTS IN RELATION TO THE POSITION OF THE FEMUR

Position of femur	Numbers (*hips*) Displacement osteotomy			Grading " as a hip " (*percentage*)			
	With external fixation	With internal fixation	Both	Excellent	Good	Fair	Poor
Satisfactory line and adducted .	118 (70 per cent)	24 (50 per cent)	142	25	18	37	20
Unsatisfactory line . . .	38 (23 per cent)	17 (34 per cent)	55	29	18	20	33
Not adducted	24 (14 per cent)	19 (38 per cent)	43	28	2	33	37
Unsatisfactory line and adducted	26 (15 per cent)	6 (12 per cent)	32	31	25	19	25

Position of femur	Grading " as an arthroplasty " (*percentage*)				Numbers (*hips*)
	Excellent	Good	Fair	Poor	
Satisfactory line and adducted .	8	30	28	34	142
Unsatisfactory line . . .	9	27	17	47	55
Not adducted	7	21	30	42	43
Unsatisfactory line and adducted	12·5	31	12·5	44	32

type of operation. This naturally affects the percentage of " poor " results to a greater extent in the smaller series of displacement osteotomy with internal fixation, but is not the whole of the explanation. The main part of the explanation may lie in the positioning of the femur. The results in relation to the position of the femur are shown in Table XXVI. I arbitrarily chose to define a satisfactory position of weight bearing as one in which, with the patient standing and the limb in a neutral abduction-adduction position, a vertical line from the centre of the head of the femur fell along the medial cortex or within the shaft of the femur but not medial to the shaft. Adduction, or otherwise, of the upper fragment of the femur was noted. This was estimated as accurately as possible from the radiographs by comparing pre-operative and post-operative films of the hip upon which the operation had been performed and the opposite hip. The fact that the position of adduction was simulated by lateral rotation was taken into account. Those cases in which the upper fragment of the femur had not become adducted gave the poorest results. Failure to obtain adduction was shown in 14 per cent of cases of displacement osteotomy with external fixation and in 38 per cent of those in which internal fixation was used. In one-quarter of the cases of displacement osteotomy with internal fixation the Trendelenburg test was positive, compared with one-sixth of the cases with external fixation (cases with mobility indices under 10 were excluded from this analysis). No relationship could be found between the positive Trendelenburg test and the length of time since operation. Of the eleven cases with internal fixation showing Trendelenburg's sign only two showed adduction of the upper fragment. Both of these were cases of congenital dislocation of the hip. The actual line of weight bearing seems less important, although the best results were seen when this line was " satisfactory " and the upper fragment of the femur was adducted. Good results were sometimes obtained when an osteotomy produced no detectable displacement or—exceptionally—produced abduction of the upper fragment.

Comment—The main drawback to displacement osteotomy with external fixation is the risk of ankylosis. Internal fixation probably lessens this risk but in this series gave fewer good results. Adduction of the upper end of the femur, seen more often when the older methods of immobilisation are used, seems to be related to the production of a good result. Displacement of the shaft of the femur producing a bone block to adduction results in a smaller percentage of good results than when some degree of adduction movement is possible.

EXCISION OF THE HEAD AND NECK OF THE FEMUR AND BATCHELOR'S OPERATION

Material—The results of seventy such operations were seen. The period of observation after operation ranged from two to seventeen years and the follow-up over the whole was 60 per cent.

The conditions for which operation was performed resembled those in the other reviews (Table XXVII). The average age of the patients was slightly lower than in the case of cup arthroplasty, but 28 per cent were over sixty at the time of operation. Eight of the seventy hips had been subjected to some other operation before, and fifteen were previously ankylosed: in other words, twenty-three were poor material.

Results—One case was rejected because the result was attributable mainly to another disability. In the remaining sixty-nine cases the best results were obtained when the operation was done for disease of a single hip (Table XXVIII). However, the highest proportion of poor results was not in the patients who had operations on both hips but in those cases of disease of both hips in which an operation was performed on one hip only. The " excellent " and " good " results in these two classes were much the same. The explanation may be that the shortening of the limb—usually about two inches—requires compensatory pelvic tilting. This would not cause symptoms if the other hip were unaffected but might do so if it were so stiff as to prevent tilting. Again, if the other hip were affected less severely pelvic tilting might occur and be responsible for pain by forcing that hip into a position of adduction. Table XXVIII shows also that there was no great difference between grading " as a hip " and " as an arthroplasty," indicating that stiffness seldom occurred.

TABLE XXVII

EXCISION OF THE HEAD AND NECK OF THE FEMUR WITH AND WITHOUT OSTEOTOMY. CONDITIONS FOR WHICH OPERATION WAS PERFORMED

(*Numbers of hips*)

Diagnosis	Batchelor's operation		Excision head and neck		Both
	Both reviews	Second review only	Both reviews	Second review only	Both reviews
Osteoarthritis	21	13	7	7	28
Congenital subluxation	2	1	—	—	2
Congenital dislocation of hip	2	—	1	1	3
Otto pelvis	1	1	—	—	1
Fracture or dislocation	5	3	3	2	8
Rheumatoid arthritis	5	1	4	2	9
Ankylosing spondylitis	4	2	3	—	7
Infective arthritis	6	4	5	3	11
Tuberculosis	1	1	—	—	1
					70

TABLE XXVIII

EXCISION OF THE HEAD AND NECK OF THE FEMUR WITH AND WITHOUT OSTEOTOMY.

(*Patients seen at second review*)

RESULTS IN RELATION TO UNILATERAL AND BILATERAL AFFECTION AND UNILATERAL AND BILATERAL OPERATION

Bilateral operation				Single operation—bilateral disease				Single operation—unilateral disease			
27 hips				16 hips				26 hips			
Grades " as an arthroplasty " (*percentages*)											
Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
4	22	56	18	(6)	(19)	(44)	(31)	19	50	19	12
26				(25)				69			
Grades " as a hip "											
7	19	63	11	(12·5)	(12·5)	(44)	(31)	58	11	23	8
26				(25)				69			

Note—Percentages bracketed where numbers less than 20.

Some of these patients were seen in the first review and again, about four years later, in the second. Table XXIX shows the grading in year groups when the two reviews are combined. The percentage of " fair " results was higher than in cup arthroplasty and in displacement osteotomy. Under five years the percentage of " poor " results was fairly high—37 per cent—but in the " over five year " group dropped to 15 per cent when assessed " as a hip " and

TABLE XXIX

EXCISION OF HEAD AND NECK OF FEMUR WITH AND WITHOUT OSTEOTOMY. RESULTS IN RELATION TO TIME ELAPSED SINCE OPERATION

(*Both reviews combined*)

Batchelor's operation and excision of the femoral head and neck

Post-operative periods	Grading in numbers—percentages in brackets								Numbers (*hips*)
	" As a hip "				" As an arthroplasty "				
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	
Under 3 years (i.e., ½–3)	2 (10·5)	2 (10·5)	8 (42)	7 (37)	—	3 (16)	9 (47)	7 (37)	19
Under 5 years (i.e., ½–5)	13	7	43	37	3	13	47	37	30
Over 5 years . .	26	15	44	15	11	30	38	21	66

Batchelor's operation

Post-operative periods	Grading in numbers—percentages in brackets							
	" As a hip "				" As an arthroplasty "			
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Under 5 years . .	4 (17)	2 (9)	11 (48)	6 (26)	1 (5)	4 (17)	12 (52)	5 (26)
Over 5 years . .	13 (31)	8 (19)	14 (33)	7 (17)	4 (10)	17 (40)	12 (29)	9 (21)

Excision femoral head and neck

Under 5 years . .	—	—	2	5	—	—	2	5
Over 5 years . .	4 (17)	2 (8)	15 (62·5)	3 (12·5)	3 (12·5)	3 (12·5)	13 (54)	5 (21)

21 per cent when assessed " as an arthroplasty." This figure is decidedly better than that for the five to ten year cup arthroplasties and for the " over five year " displacement osteotomies. Under five years there were only 20 per cent of good results " as a hip " and 15 per cent of good results " as an arthroplasty." These figures are low but when the " over five year " group is considered the percentage of " excellent " and " good " results has risen, remarkably, to 41 per cent by both methods of assessment. It should be remembered that the follow-up is less complete than that of the cup arthroplasties. It is probably comparable with that of the displacement osteotomies though the numbers are smaller.

Table XXX shows how the range of movement altered over the years. The five to seven year group was not good but, apart from this, a satisfactory range with a mobility index over 30 was maintained in at least 70 per cent of the cases. Only twenty-six hips were studied after simple excision of the head and neck. The range of movement was less than that obtained after the Batchelor operation, only 56 per cent having a mobility index of over 30 after five

TABLE XXX

EXCISION OF HEAD AND NECK OF THE FEMUR WITH AND WITHOUT OSTEOTOMY. MOBILITY INDEX RELATED TO TIME ELAPSED SINCE OPERATION

(*Both reviews combined*)

Batchelor's operation and excision of the femoral head and neck (*The figures in each range are in percentages*)

Post-operative periods	Mobility index				Numbers (*hips*)
	0–9	10–29	30–49	50 and over	
To 3 years	—	(21)	(58)	(21)	19
			(79)		
3–5 years	(9)	(27)	(37)	(27)	11
			(64)		
5–7 years	15	35	40	10	20
			50		
7–10 years	5	24	49	22	37
			71		
Over 10 years	—	(22)	(45)	(33)	9
			(78)		

Batchelor's operation. (*The figures are in actual numbers*)

Post-operative periods	Mobility index				Total number (*hips*)
	0–9	10–29	30–49	50 and over	
To 3 years	—	2	10	3	15
3–5 years	—	2	3	3	8
5–7 years	1	3	7	1	12
7–10 years	1	7	13	4	25
Over 10 years	—	1	3	2	6

Excision of the femoral head and neck. (*The figures are in actual numbers*)

To 3 years	—	2	1	1	4
3–7 years	3	5	2	1	11
Over 7 years	1	3	6	5	15

Note—Percentages bracketed where numbers less than 20.

years, and fewer than this in the " under five year " group. As to stability of the hip the Trendelenburg test was more often positive after simple excision of the head and neck than after Batchelor's operation (Table XXXI). As to relief of pain (Table XXXII): of the sixty-four hips on which Batchelor's operation had been performed 78 per cent either were not painful or caused pain that could be ignored, and 22 per cent caused more severe

pai In 85 per cent of the twenty-seven cases of excision of the head and neck the patient hac o pain or an amount that he could ignore, and in 15 per cent there was more severe pain. The esults for relief of pain were even more satisfactory in the " over five year " group. Th esults in the smaller number of patients who had simple excision of the head and neck wer rather better than those for Batchelor's operation. In fact, this operation gave relief of pai more consistently than any other operation whose results are reviewed here.

TABLE XXXI

EXCISION OF HEAD AND NECK OF THE FEMUR WITH AND WITHOUT OSTEOTOMY. RESULTS OF THE TRENDELENBURG TEST

Cases where the sign was doubtful and all those with a mobility index under 10 *have been excluded*

Post-operative period	Operation	Number of hips	
		Test negative	Test positive
Under 5 years .	Batchelor's operation . .	6	16
	Excision of the head and neck	1	3
Over 5 years .	Batchelor's operation . .	26	11
	Excision of the head and neck	3	8
For one series of cases			
Over 5 years .	Batchelor's operation . .	20	1

TABLE XXXII

EXCISION OF HEAD AND NECK OF THE FEMUR WITH AND WITHOUT OSTEOTOMY. PAIN RELATED TO TIME ELAPSED SINCE OPERATION

Cases having a mobility index under 10 *have been excluded. Figures are in actual numbers with percentages in brackets. Amount of pain is indicated thus:* 0=*no pain,* 1=*ignores,* 2=*makes concessions to,* 3=*disabling*

Post-operative period	Operation					
	Batchelor's operation (64 *hips*)		Excision of the head and neck (27 *hips*)		Both (91 *hips*)	
	Pain		Pain		Pain	
	0 and 1	2 and 3	0 and 1	2 and 3	0 and 1	2 and 3
All years . .	50 (78 per cent)	14 (22 per cent)	23 (85 per cent)	4 (15 per cent)	73 (80 per cent)	18 (20 per cent)
1 5 years . .	19 (82 per cent)	4 (18 per cent)	4	2	23 (79 per cent)	6 (21 per cent)
Over 5 years .	31 (76 per cent)	10 (24 per cent)	19 (90 per cent)	2 (10 per cent)	50 (81 per cent)	12 (19 per cent)

Comment—Rehabilitation after these operations usually requires a long time but, more particularly after Batchelor's operation, stability, relief of pain and some active movement are acquired. After five years at the latest the result is probably permanent. Many patients achieve no more than a " fair " result but " poor " results are few. The apparently greater stability after osteotomy may be due to increased pelvic support or to enhancement of the mechanical advantage of the abductor muscles.

CONCLUSIONS

General remarks—Comparison of the two reviews shows that patients with good results return more readily for a review than those with poor results. In middle-aged patients with some disability for walking an attendance of 80 per cent at least is necessary in order to obtain a representative follow-up five to ten years after operation.

An outstanding feature of all the operations reviewed is the degree of lasting relief of pain. It is rare to find that a patient with severe hip pain before operation has pain of the same severity after any of these operations at least up to ten years afterwards, and probably for much longer. Generally speaking, although in advancing years stiffness of the hip is undoubtedly a handicap, it is preferable to instability, particularly if this is progressive. A patient can adapt himself to and accept a disability that is permanent and unaltering, but instability increasing in later years can be distressing mentally and incapacitating physically.

Cup arthroplasty—There is an element of unpredictability in the results, especially the late results, of cup arthroplasty. Movement decreases and there is a tendency for pain and instability to increase after four or five years. There is little to indicate which case will be successful although the results vary according to the condition for which operation is performed. The operation gives good results, on the whole, for osteoarthritis, particularly when the operation is done on one hip only. Stability is much more important when both hips are involved, and, unless this is good in at least one hip, the results of bilateral operations are poor. " Excellent " results are not obtained in rheumatoid arthritis but few results are " poor." Operations for congenital dislocation of the hip give the most disappointing results. In operations for ankylosing spondylitis there is a high incidence of stiffening of the hip, but many patients are greatly improved in comparison to their state before operation.

Displacement osteotomy—The hazard in displacement osteotomy is ankylosis, particularly when internal fixation is not used. Relief of pain and stability are well maintained. The results in general, and for pain in particular, are less good when internal fixation is used. Adduction of the upper fragment of the femur appears to be of value in the production of a good result. In the series examined it was less often achieved when internal fixation was the method of immobilisation. The best results were obtained in cases of congenital dislocation of the hip and there were few " poor " results in cases of congenital subluxation.

Excision of the head and neck of the femur and Batchelor's operation—Rehabilitation may take a long time, but the late results are more predictable than in the other operations reviewed. A " fair " result is more likely than an " excellent " one, but late " poor " results are few. Relief of pain is better after excision of the head and neck than after any other operation reviewed.

I should like again to thank all the surgeons who joined in the research for their help and encouragement, and the nursing and administrative staffs of the hospitals for the extra work entailed. For assistance in the production of new proformae and for the initial work in analysing the results I am grateful to Mr T. E. Cowan, Statistician to the Middlesex Hospital. The later analyses were very kindly undertaken by Dr J. A. H. Waterhouse of the Department of Medical Statistics of the University of Birmingham. Special thanks are due to him for taking over a statistical analysis begun elsewhere, and to Miss Jean Powell for producing the analyses.

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THE RESULTS OF REPAIR OF THE SCIATIC NERVE

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In civil practice sciatic nerve injuries are too infrequent to permit accurate assessment of the results of treatment. This paper deals with the results of sciatic nerve repair following all types of injury, war wounds predominating (Table I).

At the beginning of the second world war the Medical Research Council appointed a committee to study the pathology and treatment of nerve injuries. This work was carried out in the centres established by the Emergency Medical Service for the treatment of both civil and war injuries. The results of these labours were published by the Medical Research Council in 1954, and this work will be referred to as the British Report.

In the United States a representative sample of nerve injuries treated throughout the country has been studied. This work, published in 1956 in a Veterans' Administration Monograph entitled *Peripheral Nerve Regeneration*, will be referred to as the American Report.

TABLE I

Cause of nerve injury	Number of cases
War wounds . .	94
Clean open wounds	13
Fractures . .	7
Traction . .	2
Pressure . .	1
Tumour . .	1

These two monographs contain the most complete studies available of nerve injury and are the indispensable bases for any further studies.

THE PATIENTS

Between 1940 and 1954, 145 patients underwent repair of the sciatic nerve or its branches. They have been observed for from three to eighteen years, with an average of 11·7 years. Although most of these patients had been followed for a number of years before discharge, as many as possible were re-examined. Just under half the number returned. Many patients had moved to other parts of Great Britain and the Commonwealth; these were asked to complete detailed questionnaires. The two groups of patients, 118 in all, comprise the basis for this report; there were 105 nerve sutures and thirteen nerve grafts. The follow-up rate is 81 per cent.

METHOD OF ASSESSMENT

The assessment of nerve recovery is difficult. Though no technique so far devised is ideal, the one suggested by Highet (1954) and used in the British centres has been followed, with modifications where necessary (Tables II and III).

This work was undertaken during the tenure of a Travelling Fellowship awarded by the National Foundation, United States. Dr Clawson is now head of the Division of Orthopaedics in the University of Washington, Seattle, Washington, U.S.A.

A nylon filament which would just bend at the weight of one gramme, mounted n a length of bicycle spoke, was used to elicit light touch. The thick skin of the sole of the oot was usually insensitive to this stimulus, and one had often to be content with recording the response—coarse touch—to stroking with the blunt end of the bicycle spoke. Pain vas elicited by the use of a sharp needle. A return of sensibility to Stage 2 or better was consid red functionally useful.

TABLE II

STAGES OF SENSORY RECOVERY

Stage	
Stage 0	Absence of sensibility in the autonomous zone of the nerve
Stage 1	Recovery of deep cutaneous pain sensibility within the autonomous zone
Stage 2	Recovery of some degree of superficial pain and tactile sensibility within the autonomous zone
Stage 2+	Return of superficial pain and tactile sensibility throughout the autonomous zone, but with some over-response persisting
Stage 3	Return of superficial pain and tactile sensibility throughout the autonomous zone with disappearance of over-response
Stage 4	Return of sensibility as in Stage 3 with the addition that there is recovery of two-point discrimination

TABLE III

STAGES OF MOTOR RECOVERY

Stage	
Stage 0	No contraction
Stage 1	Perceptible contraction in the proximal muscles
Stage 1 (*)	Contraction in the proximal muscles graded according to their power*
Stage 2	Return of perceptible contraction in both proximal and distal muscles
Stage 3	Return of function in both proximal and distal muscles to such an extent that all important muscles are able to act against gravity
Stage 4	Return of function as in Stage 3 with the addition that all synergic and isolated movements are possible
Stage 5	Complete recovery

* The numeral in parenthesis in this division represents the power of the muscles tested according to the method adopted by the Medical Research Council: (0) Complete paralysis; (1) Flicker of contraction; (2) Contraction only with gravity eliminated; (3) Contraction against gravity only; (4) Contraction against gravity and some resistance; (5) Contraction against powerful resistance or normal power.

Although assessment of the finer degrees of motor recovery can be difficult, the division between functionally useful and valueless recovery is quite definite. The long muscles of the foot must be acting at M 1 (4) or more—that is, against gravity and some resistance—to be functionally useful. This is most apparent in foot-drop from lateral popliteal paralysis. It is necessary to lift the foot against gravity and the weight of the shoe in order to permit reasonably normal walking; nothing less than this degree of recovery is worth while.

TABLE IV

RESULTS OF REPAIR OF THE DIVISIONS OF THE SCIATIC NERVE

	Level of lesion	Medial popliteal						Lateral popliteal						Posterior tibial			
		Hip	F.R.* (per cent)	Thigh	F.R. (per cent)	Knee	F.R. (per cent)	Hip	F.R. (per cent)	Thigh	F.R. (per cent)	Knee	F.R. (per cent)	Calf	F.R. (per cent)	Ankle	F.R. (per cent)
Motor recovery	M 0	1		4		0		3		9		7		4		3	
	M 1 (1–3)	1		4		0		5		13		9		0		1	
	M 1 (4–5)	2	50	32	80	3	100	1	11	14	40	6	39	1	55	1	67
	M 2+	0		0		0		0		1		4		4		4	
Sensory recovery	S 0	2		10		0		1		5		2		3		2	
	S 1	0		5		1		2		6		3		0		1	
	S 2	2	50	23	69	1	67	5	67	22	70	14	81	4	67	4	67
	S 3	0		2		1		1		4		7		2		1	
	S 4	0		0		0		0		0		0		0		1	

* F.R. = Functional recovery.

ANALYSIS OF RESULTS

In analysing the results of repair of the sciatic nerve it is convenient to study the two divisions separately (Table IV).

MEDIAL POPLITEAL NERVE

Motor—There were forty-seven cases of medial popliteal nerve suture. In 79 per cent there was functionally useful motor recovery, M 1 (4) or better. Eleven per cent showed no evidence of recovery. The calf muscle is the first and often the only muscle to recover. There may be good power in the calf and none in the other long muscles. In 50 per cent of the cases showing some motor recovery the tibialis posterior was active but in only 22 per cent was it functionally satisfactory. Twelve per cent of the cases exhibited some contraction in the long flexors of the toes, but in none was it useful. No patient showed clinical recovery in the intrinsic muscles of the foot.

These results are somewhat better than those recorded in the British Report, where only 56 per cent of the cases showed functional motor recovery. The earlier reported cases had been followed from one to five years; it is not surprising that some patients developed more power later. Because of a different system of grading it is difficult to make an accurate comparison with the results recorded in the American Report. However, there seems to be general agreement with the one exception that in 21·3 per cent of the American patients there was recovery in the intrinsic muscles of the foot, and in 8·1 per cent these muscles acted against some resistance. We are unable to explain this difference.

Sensory—In 62 per cent of the patients there was functionally useful sensory recovery, S 2 or better. There is no significant difference in the return of sensory recovery in the sole of the foot whether it was after suture of both medial and lateral popliteal nerves or suture of the medial popliteal nerve only, the lateral popliteal being intact.

Again, the frequency of good sensory recovery is much higher than that previously recorded, 27 per cent, in the British Report. However, it was noted in that Report that 80·5 per cent of the patients gave some response to pinprick, and it is likely that there has been a further return of sensory function with the passage of time. This percentage agrees well with

the American figure of 73·6 per cent. An example of the difficulties encountered in testing sensibility in the sole is the wide range of sensory recovery recorded in the American Report, which varied from 50 per cent recovery in cases examined in Chicago to 90 per cent in San Francisco.

LATERAL POPLITEAL NERVE

Motor—Seventy-two lateral popliteal sutures were performed. In 36 per cent there was functionally useful motor recovery. This agrees closely with the previously reported figure of 36 per cent in the British Report and 29·4 per cent in the American Report.

Sensory—In 74 per cent of the cases there was functionally useful sensory recovery. With the wide variation in the extent of the cutaneous sensory zone of the lateral popliteal nerve, and the degree of overlap in this area, this result is not remarkable; and because of the possibility of overlap, sensory recovery is not a reliable criterion of re-innervation. Absence of sensibility in this area is a negligible handicap.

Correlation between motor and sensory recovery—This was possible only in the case of the medial popliteal nerve.

Satisfactory motor and sensory recovery . .	27
Satisfactory motor with little or no sensory recovery	9
Satisfactory sensory with little or no motor recovery	2
No useful motor or sensory recovery . . .	9

POSTERIOR TIBIAL NERVE

There were eighteen cases of posterior tibial nerve suture. In twelve there was useful sensory recovery in the sole. There was no useful return of function in the small muscles of the foot, though in eleven cases there was some motor return.

FACTORS INFLUENCING RECOVERY

All patients were treated in a standard manner. Only after detailed examination was exploration and suture carried out. There was only one case of (delayed) primary suture. Secondary suture was carried out as soon as conditions were favourable—that is, when 1) the wound was healed; 2) a fracture, if present, was reasonably stable; 3) the knee joint flexed to 90 degrees or more.

The nerve lesion was resected until the nerve bundles pouted freely with no evidence of intraneural scarring. Suture was carried out after full mobilisation so that there was no tension on the suture line. The suture materials used were fine silk, human hair or plasma clot. Except in the earliest cases, the tourniquet was released and bleeding completely controlled before the suture was performed; several earlier cases had shown separation of the suture line thought to be due to bleeding from the nerve ends; resuture had been necessary. All specimens were examined histologically for evidence of fibrosis that would preclude a satisfactory result.

After operation a plaster spica was applied with the hip extended and the knee appropriately flexed. At the end of three weeks the hip was released and after four weeks from the date of operation a turnbuckle was applied at the knee which was gradually extended during the next six weeks. In later cases in the series an apparatus designed to block extension but to allow flexion was used while the knee was being gradually extended. Daily passive movement of all joints and galvanism three to six times a week, to maintain muscle bulk, were given as soon as practicable. Three variables have been examined: the interval between injury and repair, the extent of the gap to be closed after resection of the damaged nerve ends, and the level of the nerve lesion.

Time of repair—After suture of the medial popliteal nerve there is a relationship between the interval before repair and the proportion of good results, whether motor or sensory recovery is used as the criterion (Table V). The earlier the suture the better the result. However, in the lateral popliteal nerve, where motor recovery alone can be used as a criterion, there seems to be no relation between the time of suture and recovery, up to twenty-four months. We have

TABLE V

TIME OF REPAIR RELATED TO RECOVERY

Medial popliteal nerve			
Interval between injury and repair *(months)*	**Sensory recovery**		
	S 0 – 1	**S 2 or better**	**Good recovery *(per cent)***
Less than 1 .	0	2	100
1 to 6 . .	5	15	75
7 to 12 . .	7	13	65
13 to 24 . .	3	1	25
Over 24 . .	1	0	0
Interval between injury and repair *(months)*	**Motor recovery**		
	M 0 – M 1 (3)	**M 1 (4) or better**	**Good recovery *(per cent)***
Less than 1 .	1	1	50
1 to 6 . .	2	18	90
7 to 12 . .	6	14	70
13 to 24 . .	2	2	50
Over 24 . .	0	1	100
Lateral popliteal nerve			
Interval between injury and repair *(months)*	**Motor recovery**		
	M 0 – M 1 (3)	**M 1 (4) or better**	**Good recovery *(per cent)***
Less than 1 .	5	2	29
1 to 6 . .	18	11	38
7 to 12 . .	19	10	35
13 to 24 . .	3	2	40
Over 24 . .	2	0	0

no explanation to offer for this discrepancy between the results of suture of the medial popliteal and of the lateral popliteal nerve.

Gap in nerve—Up to the point of obtaining a satisfactory suture without tension—in the adult the maximum is about twelve centimetres—the size of the gap makes no difference in recovery of motor or sensory function (Table VI). This is in contrast to repair of the

median and ulnar nerves, where the larger the gap the worse the recovery (Nicholson and Seddon 1957). However, mobilisation of the sciatic nerve and the consequent interference with its blood supply was relatively and often absolutely less than in repair of nerves in the arm. Often all that is necessary to close moderate gaps in the sciatic nerve is local mobilisation and flexion of the knee. A second explanation may be the relationship of the extent of the gap in the nerve to its total length. The sciatic nerve, being the longest in the body, can better tolerate the post-operative stretching. An exception to this may be after suture near a joint where the sutured area becomes tethered by scar; stretching will then be excessive in the nerve distal to this point (Highet and Sanders 1943).

TABLE VI

GAP IN NERVE RELATED TO RECOVERY

Gap in nerve *(centimetres)*	Medial popliteal nerve			Lateral popliteal nerve	
	Number of cases	Motor: good results *(per cent)*	Sensory: good results *(per cent)*	Number of cases	Motor: good results *(per cent)*
0–2 . .	2	50	50	2	0
2–4 . .	9	78	67	18	33
4–6 . .	13	85	69	23	31
6–12. .	17	77	59	22	45
Over 12 .	—	—	—	1	0

After the closure of very extensive gaps in the sciatic nerve recovery can be interfered with by endoneural scarring, the post-operative stretching of the nerve producing a lesion similar to that caused by traction (Highet and Holmes 1943).

Level of suture—Although the numbers are too small to be significant it appears that the more proximal a suture the less satisfactory the result (Table IV). Yet nerve suture can be performed at any level with the possibility of a satisfactory result. In the medial popliteal nerve motor recovery is always somewhat better than sensory recovery. After posterior tibial nerve suture adequate sensory recovery is no more frequent than after more proximal sutures.

NERVE GRAFTS

Autogenous nerve grafting has an established position in peripheral nerve surgery (Bunnell and Boyes 1939, Sanders 1942, Gutmann and Sanders 1942, Seddon 1947). It is more satisfactory for the repair of small nerves because of the greater prospect of survival of the small and preferably single graft; a large graft may become necrotic (Holmes 1947). The use of the lateral popliteal nerve for the repair of the medial has been regarded unfavourably and it is therefore worth while to review the thirteen nerve grafts in this series of sciatic nerve repairs.

A detailed account of the technique of nerve grafting will be found in chapter 9 of the British Report. A cable graft of three strands of a smaller nerve to make up the size of a larger one has been used in several cases. This is effective for the smaller branches, but not for the major trunks of the sciatic. Dividing a useless portion of the lateral popliteal into two strands and using it to bridge the medial popliteal was done with partial success.

Of the lateral popliteal grafts to the medial popliteal in the thigh, of which there are nine cases, four were followed by useful motor recovery; two patients showed some sensory return.

If the operations in which one strand was used are excluded, three of the four patients had useful motor recovery. However, if the main goal is to restore sensibility in the foot there is little likelihood that grafting can achieve it, for only two of the nine patients showed sensory recovery of a useful degree. In view of the possibility of overlap from the saphenous area accounting for some of the sensory return it is difficult to justify nerve grafting for sciatic

TABLE VII
NERVE GRAFTS

Graft Lateral popliteal to medial popliteal	Length *(centimetres)*	Result	
		Motor	Sensory
One strand	4·5	M 0	S 0
	3	M 1 (4)	S 1
	16	M 0	S 2
	7·5	M 0	S 1
	11·3	M 1 (1)	S 0
Two strands	9	M 1 (4)	S 1
	8·5	M 1 (4)	S 2
	10	M 1 (3)	S 0
	10	M 1 (4)	S 0
Cable graft—3 strands			
Sural nerve to lateral popliteal	3	M 1 (4)	S 2
Sural nerve to posterior tibial	9	M 0	S 3
Fibular communicating nerve to posterior tibial	5	M 0	S 3
Lateral plantar nerve to medial plantar nerve	3	M 0	S 2

lesions on this basis. Although some patients did develop a fair degree of power in the calf muscle, function was little better than in patients with total sciatic paralysis. It is therefore doubtful whether nerve grafting for repair of a lesion of the main trunk of the sciatic nerve should be attempted.

SUMMARY

1. The results of repair of the sciatic nerve and of its main divisions have been analysed in a series of 118 cases, the patients having been under observation for three to eighteen years (average 11·7 years).

2. A result was satisfactory if there was some return of sensibility throughout the autonomous zone (the area of skin supplied exclusively by the damaged nerve) and if the more important muscles of the leg were capable of contraction against gravity and resistance.

3. When the whole of the sciatic nerve is damaged it is necessary to present the results separately for the lateral and medial popliteal divisions.

4. Of forty-seven cases of repair of the medial popliteal nerve 79 per cent showed useful motor and 62 per cent useful sensory recovery. In three out of four cases the correspondence between the degree of motor and of sensory recovery was fairly close.

5. Of seventy-two cases of repair of the lateral popliteal nerve 36 per cent showed useful motor and 74 per cent useful sensory recovery. The latter figure must be regarded with some

reserve because sensory " recovery " in the lateral popliteal zone may be due to the ingrowth of nerve fibres from contiguous normally innervated skin. Thus it is not possible to correlate motor and sensory recovery.

6. In eighteen cases of repair of the posterior tibial nerve, there was useful sensory recovery in the sole in twelve. But although there was evidence of recovery in the plantar muscles in eleven cases it was functionally valueless.

7. In repair of the medial popliteal nerve the result was better if suture had been carried out early. In repair of the lateral popliteal nerve there was no evidence that delay was harmful; but the proportion of good results was so low (as judged by motor function alone, sensory recovery being often extraneous) that this exception to a general rule cannot be taken very seriously.

8. Gaps of up to twelve centimetres—estimated after resection of the damaged nerve ends—could be closed without difficulty by the usual technique, and the extent of the gap up to that limit had no influence on the prognosis. The closure of larger gaps, when the knee must be flexed beyond a right angle, is not compatible with good recovery because the post-operative stretching of the nerve causes serious intraneural damage.

9. Nerve grafting has given poor results in repair of the sciatic nerve.

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THE LATE CONSEQUENCES OF SCIATIC NERVE INJURY *

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In the management of nerve injuries it is first necessary to determine whether the lesion is degenerative (neurotmesis or axonotmesis) or non-degenerative (neurapraxia). Paralysis that recovers quickly is due to neurapraxia and gives little trouble. Cases of sciatic neurotmesis and axonotmesis, or a combination of the two, have been studied to determine the late results with particular reference to permanent disability.

THE PATIENTS AND THEIR INJURIES

In the Nerve Injuries Unit at the Wingfield Morris Orthopaedic Hospital, Oxford, later transferred to the Institute of Orthopaedics, Royal National Orthopaedic Hospital, 401 patients with sciatic nerve injury were treated between 1940 and 1954. Three hundred and twenty-nine patients have been followed for periods of between three and eighteen years; 143 were recalled for re-examination in connection with this report, and questionnaires were sent to the remainder to supplement the information available in the records. Included in the 329 are 118 cases of sciatic nerve repair which have been reported in another paper (Clawson and Seddon 1960). The site and nature of the lesions are shown in Table I.

FUNCTIONAL GRADING

Method of assessment—The neurological results were determined by the methods recommended in the Medical Research Council Report and summarised by Clawson and Seddon (1960).

The assessment of function is often difficult, because the patient's temperament and his reaction to the injury are important yet hard to define. One patient with a total sciatic lesion is a rock climber and has done some of the more difficult climbs in Switzerland. Another, with a total lateral popliteal paralysis, is a jet pilot in the Royal Air Force; he wears no apparatus, plays eighteen holes of golf and, despite a marked foot-drop, does not consider himself handicapped. At the other extreme, a patient with only slight lateral popliteal paresis insists on wearing toe-raising apparatus, says that he cannot walk more than a quarter of a mile because the leg tires, and for this reason feels that he is severely handicapped. We have taken into account the subjective complaints as well as the objective findings, while endeavouring to keep the classification of results as simple as possible. The following five grades of function have been devised; grades I to III are considered satisfactory:

Grade I	Perfect foot or as good as the other.
Grade II	Can walk any reasonable distance without pain; wears normal footwear and is fully active.
Grade III	Can walk any reasonable distance with special shoes, pads or apparatus, with little or no pain; no disabling over-response to cutaneous stimuli; can follow his occupation.
Grade IV	Can walk less than one mile; pain; very troublesome over-response; forced to accept less paying work because of the injury; pressure ulcers or sores.
Grade V	Unable to work because of persistent pressure sores, ulcers or incapacitating pain; amputation.

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† This work was undertaken during the tenure of a Travelling Fellowship awarded by the National Foundation, United States. Dr Clawson is now head of the Division of Orthopaedics in the University of Washington, Seattle, Washington, U.S.A.

RESULTS

Total sciatic paralysis—The results after total sciatic paralysis are shown in Table II. f the neurological is compared with the functional result it is found that, while 65 per cent f the patients with good motor recovery had satisfactory function, no less than 50 per cent o hose

TABLE I

CLINICAL DETAILS IN 329 CASES OF SCIATIC NERVE INJURY

Nerve involved	Number of cases
Entire sciatic	154
Lateral popliteal only	98
Medial popliteal only	16
Posterior tibial	35
Anterior tibial	8
Peroneal	1
Combination of the nerves of the calf	17
Site of lesion	**Number of cases**
Hip	63
Thigh (from the inferior gluteal border to the upper end of the popliteal fossa)	126
Knee	85
Calf	43
Ankle	12
Type of lesion	**Number of cases**
Complete division of the nerve	133
Incomplete division of the nerve	131
Others	65
Etiology*	**Number of cases**
War injuries	210
Traction injuries	53
Fractures (in association with the nerve injury)	18
Clean wounds	19
Injection into the buttock	10
Dislocation or fracture dislocation of the hip	21
Compression or ischaemia	29

* In some cases there was more than one possible cause, which is the reason why this list adds up to 366, thirty-seven more than the number of cases.

with poor motor recovery also had satisfactory function (Figs. 1 to 3). Function was satisfa tory in 76 per cent of the patients with good sensory recovery, but in only 38 per cent of hose with poor sensory recovery. Thus the functional result is not wholly dependent on the d gree

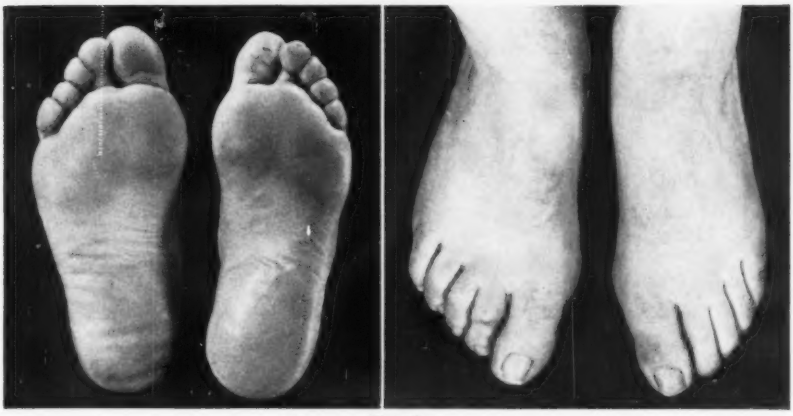

FIG. 1

Total left sciatic paralysis of fourteen years' duration. Sutured. Neurological recovery: medial popliteal—none; lateral popliteal—poor. Functional Grade III. Note the excellent condition of the foot with almost complete sciatic paralysis.

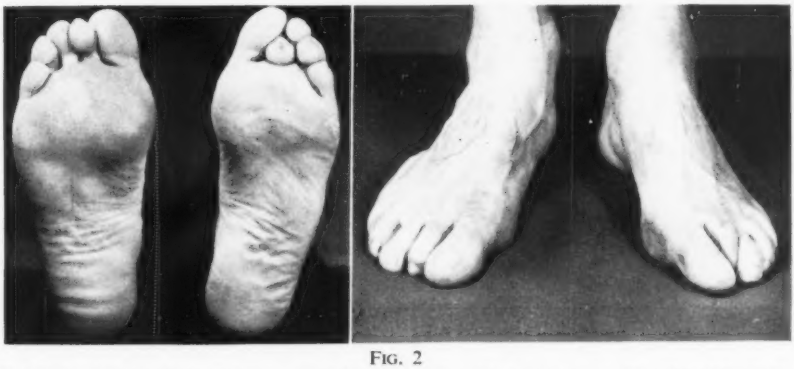

FIG. 2

Total left sciatic paralysis of sixteen years' duration. Sutured but no recovery. Functional Grade II. Work panel wiring, very active; wears normal footwear. Hammer toe should be corrected.

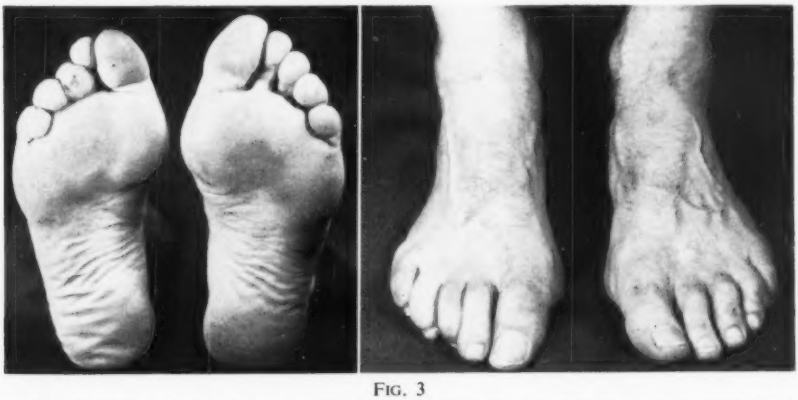

FIG. 3

Total right sciatic paralysis of thirteen years' duration. Sutured. Neurological recovery: most of the muscles of the leg act strongly, but only deep pain sensibility has returned. Functional Grade II. Normal footwear, can walk ten miles. No complaints from clawing of toes or sore beneath the third toe.

of nerve recovery. One-third of the patients with no useful sensory recovery attained a satisfactory functional result; nevertheless, the better the nerve recovery, the better the function, though this applies more to sensory than to motor recovery.

Lateral popliteal nerve (Table III)—The correlation of nerve recovery with function is even less apparent in the lateral popliteal nerve where 83 per cent of the patients with poor motor recovery had satisfactory function as compared with 96 per cent of the patients with good

TABLE II

RESULTS: TOTAL SCIATIC PARALYSIS

Grade of functional recovery		Percentage of cases	
Satisfactory	I	0	64
	II	12	
	III	52	
	IV	27	
	V	9	

TABLE III

RESULTS: LATERAL POPLITEAL NERVE

Grade of functional recovery		Percentage of cases	
Satisfactory	I	6	89
	II	38	
	III	45	
	IV	10	
	V	1	

TABLE IV

RESULTS: MEDIAL POPLITEAL NERVE

Grade of functional recovery		Percentage of cases	
Satisfactory	I	4	87
	II	30	
	III	53	
	IV	13	
	V	0	

motor recovery. Eighty per cent of the patients with poor sensory recovery had satisfactory function compared with 92 per cent of the patients with a good sensory result (Fig. 4). Few people with this lesion are permanently handicapped. Only 11 per cent had unsatisfactory function; however, the better the nerve recovery the better the function.

Medial popliteal nerve (Table IV)—Here there is a surprising lack of correlation between nerve recovery and good function (Fig. 5); 86 per cent of the patients with good motor recovery and 85 per cent of those with poor motor recovery had a satisfactory functional result. There was no closer correlation with sensory recovery; whether it was good or bad 85 per cent of the patients showed a satisfactory functional result. Medial popliteal paralysis is not as severe a handicap as might be expected, though the better grades of functional recovery were seen in those patients with better nerve recovery.

TYPES OF INJURY

Although war injuries predominated, brief reference must be made to other types of damage, which might have a bearing on prognosis. In the following paragraphs only the quality of neurological recovery is referred to.

FIG. 4

Left lateral popliteal paralysis of thirteen years' duration. Eight centimetre gap. No repair. No motor recovery but good sensibility. Functional Grade III. Wears toe-raising appliance.

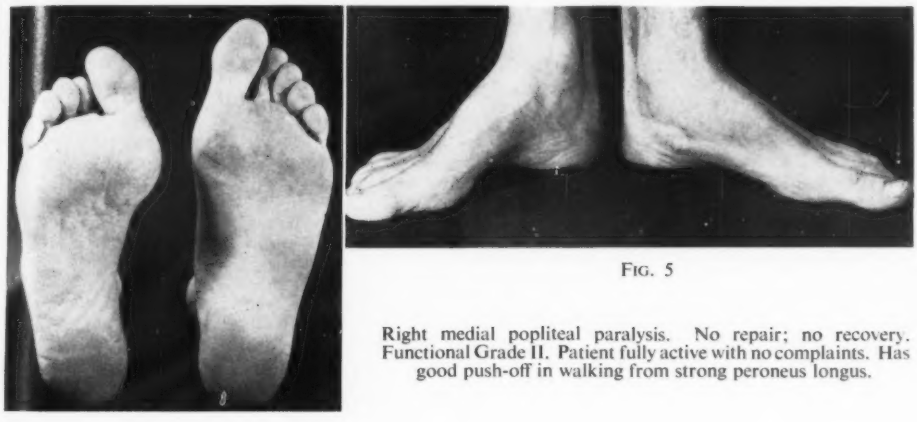

FIG. 5

Right medial popliteal paralysis. No repair; no recovery. Functional Grade II. Patient fully active with no complaints. Has good push-off in walking from strong peroneus longus.

Clean wounds—In nineteen cases there were clean wounds, eight involving the posterior tibial nerve. The quality of recovery was well above the average: in four-fifths of the cases there was some motor recovery and there was useful sensory recovery in all. Nevertheless, two-thirds of these patients exhibited symptoms due to sensory over-response.

Injection injuries—There were ten sciatic nerve injuries due to injections into the buttock, and in seven both divisions of the nerve were involved. The substances injected were quinine and atebrin, one case; heparin, one case; and sulphonamide compounds in eight cases. All patients showed some recovery but in none was it complete. The variability of recovery was such that the initial degree of paralysis gave no indication of what the final recovery would be.

Pressure—There were seven cases of lateral popliteal paralysis due to pressure in which a complete reaction of degeneration was present. In all there was useful sensory recovery and in four satisfactory motor recovery.

Ischaemia—There were eight cases in which ischaemia of nerves in the calf was the cause of the paralysis. In four there was excellent motor recovery and in five a satisfactory return of sensibility.

Traction injuries (Table V)—Fifty-three traction injuries were studied and in thirteen the nerve was explored. Unless complete rupture was revealed the appearance of the nerve gave no clue to the prospects of recovery. The prognosis was unaffected by exploration. The quality of recovery was a little above the average.

TABLE V

RECOVERY AFTER TRACTION LESIONS

Level of lesion	Number of cases	Nerve	Functional motor recovery		Functional sensory recovery	
			Traction *(per cent)*	All cases *(per cent)*	Traction *(per cent)*	All cases *(per cent)*
Hip	27	Lateral popliteal component (21)	52	44	95	73
		Medial popliteal component (18)	83	70	89	75
Knee	26	Lateral popliteal . . .	58	52	85	80

FACTORS INFLUENCING THE FUNCTIONAL RESULT

Age of patient—As most of these patients had suffered war injuries most were young adults. There were only fourteen patients under fifteen years of age and thirty-seven over thirty-five. There are too few cases in these two groups to permit comparison but it appears that age has little influence on nerve regeneration. However, functional recovery was better in the younger patients. After nerve suture in children sensory recovery is of better quality than in the adult. In the elderly, factors other than the nerve injury frequently influence the functional result.

TABLE VI

INCIDENCE OF PAIN IN RELATION TO SITE OF LESION

Nerve injured	Percentage of patients with pain
Sciatic . .	58
Medial popliteal	56
Lateral popliteal	43
Level of lesion	**Percentage of patients with pain**
Hip. . .	64
Thigh . .	48
Knee . .	46
Calf and ankle .	64

SENSORY PHENOMENA

Pain (Table VI)—Pain is the most common complaint of patients with sciatic nerve injury and was present in 175 cases (53 per cent). It was variously described as a deep or a constant ache; aching when tired, or with temperature change; a throbbing or dull nagging pain. In addition, there were three patients in this series with typical causalgia treated by sympathectomy with marked relief of symptoms. A study of these three cases adds nothing to what has already been reported on this subject.

There is no correlation between pain and the nerve involved or the site of the lesion. The same is true of the type of lesion; thus 57 per cent of patients with traction lesions, 52 per cent of those whose nerves had been sutured, and 53 per cent of all patients had pain. There is no relationship between pain and nerve recovery. The pain is, however, generally less severe in patients with little or no recovery; and it is less marked in those with good recovery than in the larger middle group with partial recovery.

Paraesthesiae—Paraesthesiae—tingling, pins and needles and burning—were noted in 21 per cent of all patients in this series. No particular reason for their occurrence could be found.

Over-response—This term is used to describe an exaggerated and painful response to an ordinary stimulus. It can vary from a very uncomfortable sensation when walking to complete

TABLE VII

OVER-RESPONSE

Level of lesion	Number of patients with over-response	Lateral popliteal division	Medial popliteal division	Percentage of total patients in each group with over-response
Hip . .	22	3	19	37
Thigh .	57	0	57	55
Knee .	14	6	8	40
Calf. .	15	1	14	47
Ankle .	8	0	8	67

inability to bear weight on the foot unless it is protected by a thick rubber pad in the shoe. The most frequent complaints were inability to walk without special shoes, and severe pain when stepping on an irregular surface. Walking along a beach or climbing a ladder was impossible. None of the patients with over-response felt that it was regressing with time, but many had learned to adjust themselves to it. Most of them were reasonably comfortable when wearing a heavy-soled shoe containing a thick sponge rubber pad.

When over-response is present the limb is sharply withdrawn if the affected area is stroked, or pricked with a pin. Thirty-five per cent of all patients, 54 per cent of those with medial popliteal lesions and only 3·5 per cent of those with lateral popliteal lesions presented this sign. In 4 per cent of patients with total medial popliteal paralysis who complained of over-response, the sensitive zone was at the periphery of the saphenous area on the sole.

Because over-response is disabling, its absence or disappearance is one of the conditions for good sensory recovery.

The relationship of over-response to the level of the lesion has a bearing on the desirability of repair of a severed nerve (Table VII).

Eight of the twelve patients with posterior tibial lesions at the ankle exhibited over-response. Of the four who did not, one had complete insensibility of the sole following wide resection of the nerve; another, an adult of twenty-four years, was treated by early secondary suture following a clean wound; and the other two were children eight and twelve years of age. Over-response may be a troublesome feature after nerve suture at any level in the lower limb. After suture at the level of the hip or in the thigh the benefit from the return of power in the calf muscle may outweigh the risk that over-response may develop. But it is questionable whether distal lesions of the posterior tibial nerve should be repaired unless conditions are very favourable. In these patients an anaesthetic sole is of little consequence if the saphenous

and sural nerves are intact. Motor recovery in the foot after posterior tibial nerve suture is functionally useless. Perhaps posterior tibial nerve suture should be done only in children.

Sensory recovery by overlap—The behaviour of the zone of cutaneous sensory loss presents some interesting features. There is much individual variation in the area supplied by a particular sensory nerve. There is also the phenomenon of shrinkage of the anaesthetic area which occurs in the absence of regeneration and is due to the ingrowth of nerve fibres from the adjacent normally innervated skin (Weddell, Guttmann and Gutmann 1941).

In this series there were six patients with large gaps in the medial or lateral popliteal nerves (5–9 centimetres) where no repair was attempted, yet fair sensibility returned in the entire denervated zone (Fig. 4). Twenty-nine other patients with complete and irreparable lesions showed no motor recovery, but there was fair sensory recovery. We do not know whether this is due to the ingrowth of fibres from adjacent innervated zones or to re-innervation by sensory fibres which have "jumped the gap." Nerve biopsy distal to the lesion and nerve block above it should provide the answer.

VASOMOTOR AND TROPHIC DISORDERS

The vasomotor and trophic changes following a nerve lesion are well known. They may be present initially and disappear, whereas in some patients they may become progressively more prominent.

It is important to examine the degree to which these complaints may be disabling and their relationship to other phenomena. One-third of all patients studied showed some of the following changes. Most complained of coldness of the affected limb; others exhibited erythema, pigmentation, thin shiny skin, nail changes and oedema.

Although initially the skin temperature is raised owing to the autonomic paralysis, it soon becomes and remains subnormal. None of the patients in this study showed increased warmth of the extremity except those with partial lesions who had been subjected to sympathectomy. Coldness of the affected limb was present in 95 per cent of patients with vasomotor or trophic complaints. It was often associated with an ache and, while never disabling, some patients found it annoying and disagreeable. Sixty-nine per cent of all patients with involvement of

TABLE VIII

VASOMOTOR AND TROPHIC DISORDERS

Level	Percentage of cases at each level
Hip	65
Thigh	58
Knee	34
Calf	42
Ankle	25

both divisions of the sciatic nerve exhibited vasomotor and trophic disorders. Seventy-one per cent of patients with medial popliteal lesions, and 35 per cent of those with lateral popliteal lesions were similarly affected. Patients with lesions in continuity had fewer complaints than those with complete division, regardless of the eventual degree of nerve recovery. There was no correlation between motor recovery and the incidence of vasomotor and trophic disorders; good motor recovery occurred in roughly half the cases, whether or not these changes were present. As would be expected, there was a connection between sensory recovery

and vasomotor and trophic disorders: when the latter were present good sensory recovery had occurred in 46 per cent of the patients, whereas 85 per cent of patients without such complaints showed good sensory recovery.

Vasomotor and nutritional changes are more severe in proximal than distal lesions (Table VIII).

The complaint of coldness is attributed to the vaso-constrictor action of low temperature on denervated blood vessels (Lewis and Landis 1930). It is less liable to be present where there has been good sensory recovery because the autonomic fibres run and regenerate with the sensory. However, this may not be the whole answer. In poliomyelitis coldness of a limb, although a direct result of increased peripheral vascular tone (Trott, Nesline and Green 1951), is certainly closely associated with motor paralysis. In paralysis caused by nerve injury the skin disorders and nail changes may to some extent be consequent on the motor paralysis.

PRESSURE SORES

A pressure sore is the most serious consequence of sciatic nerve injury, but its incidence is less than is commonly believed. Forty-five patients (14 per cent) suffered from pressure sores at some time or other. In forty-three the sciatic nerve was damaged; in two the lateral popliteal alone, but in both of these the ulceration was due to factors other than the nerve injury; one ulcer developed over a split-skin graft and the other was caused by a plaster used to treat a fracture nine years after the nerve injury.

FIG. 6

Total sciatic paralysis; lateral popliteal graft to medial popliteal nerve. Calf muscle strong; pain sensibility alone in the sole. Persistent ulcer on the great toe due to a contracture in 10 degrees of flexion.

In thirty-eight cases—88 per cent of the forty-five—the sore appeared within two years of the nerve injury. In twelve it was caused by a plaster or splint; all but two of these healed promptly without recurrence. Nineteen of the thirty-eight patients continued to have trouble for longer than four years, some for as long as they were followed. In all of them fixed deformity was the main contributory factor (Figs. 3 and 6). Patients with no sensibility in the sole were twice as prone to ulceration as patients with good sensory recovery; yet in over half the patients with persistent ulceration there was fair sensibility in the sole.

Impairment or loss of sensibility in the sole of the foot is far less important than fixed deformity. Every patient with persistent ulceration also suffered from fixed deformity of the foot or toes.

PALLIATIVE SURGERY

Tarsal arthrodesis—The commonest reconstructive operation for sciatic palsy was the Lambrinudi arthrodesis for foot-drop, which was performed in twenty cases. Only half of the patients were satisfied with the result.

The criteria of success were: 1) correction of the foot-drop, 2) no more pain in the foot than before the operation, and 3) function at least as good as before the operation. By this standard the operation was successful in only five—one-quarter—of the cases. The complaints in the fifteen unsuccessful cases were: more pain (thirteen patients); varus deformity causing symptoms (ten patients); swelling of the ankle (four patients); foot-drop greater than 30 degrees

(four patients); still wearing apparatus (three patients); poorer function after the operation (three patients).

Analysis of the unsuccessful cases explains the shortcomings of the Lambrinudi operation. Technical failures might explain some of the difficulties, but this does not alter the basic weaknesses of the procedure.

Pain—The pain was centred in one of three places: 1) about the ankle joint; 2) over the dorsum of the foot where in three cases radiography demonstrated non-union between the

FIG. 7

Lambrinudi arthrodesis for foot-drop. Pain and slight swelling over fibrous union between talus and navicular bone.

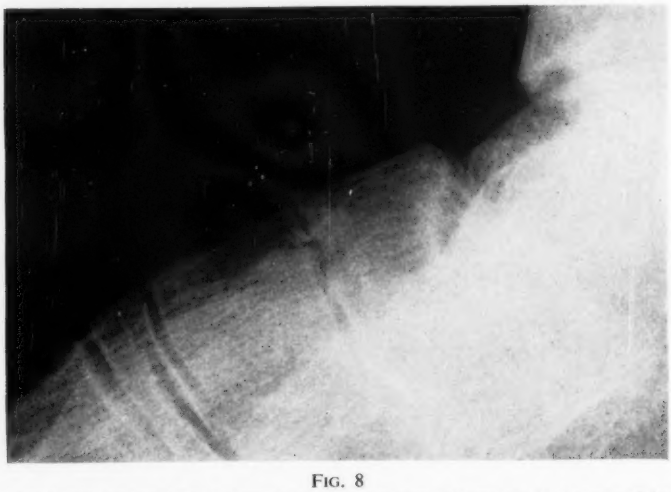

FIG. 8

Lambrinudi arthrodesis for foot-drop. There was an ache across the dorsum of the foot aggravated by walking. Note degenerative changes in navicular-cuneiform joint.

talus and the navicular bone (Fig. 7); another possible cause of pain over the dorsum of the foot was increased strain of the mid-tarsal joints with secondary arthritis (Fig. 8); 3) about the lateral malleolus where the decreased height of the foot caused the lateral malleolus to impinge on the calcaneum or to rub on the top of the shoe.

Swelling—It is not certain what causes persistent post-operative swelling. It may be associated with failure of fusion or be secondary to arthritic changes.

Persistence of foot-drop—Sometimes the foot-drop, although corrected initially, reappeared. This was due to stretching of the medial and lateral ligaments of the ankle which allowed the joint to open anteriorly (Fig. 9). Less commonly, the forefoot also may become more plantarflexed.

Fixed deformity—If the usual pattern of weight bearing is important in the normal foot it is more so after tarsal arthrodesis, which abolishes the lateral movement required when the patient is walking on an irregular surface; and even more so if the sole of the foot is more or less insensitive. A varus deformity after Lambrinudi's arthrodesis is due to inaccurate operative technique, and adds greatly to a patient's disability (Fig. 10). A supple foot with no deformity even though paralysed is far better than a fixed deformed foot that does not drop.

FIG. 9
Lambrinudi arthrodesis for foot-drop. The ankle joint opens anteriorly.

Functionally worse after operation—If the results of the Lambrinudi operation were judged only on the ability of the patient to dispense with apparatus because the foot-drop had been controlled, 80 per cent of the cases could be considered satisfactory. Yet, as has been shown, only a quarter of the patients were satisfied. The observation that the foot was less useful after the operation came from men who had worn apparatus for some years before the stabilisation had been performed. They had been able to walk fast, cover considerable distances without tiring, and even run without stumbling. They had had less discomfort with the apparatus. Many patients at various times had been asked if they would like an

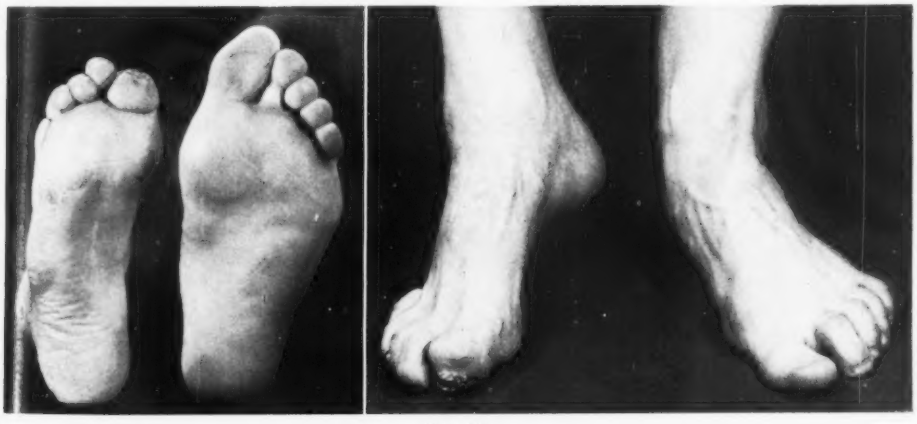

FIG. 10
Right sciatic injury ten years previously. Repaired by a graft from the lateral popliteal nerve to the medial popliteal. Calf muscle aching strongly but only deep pain sensibility in the sole. Lambrinudi arthrodesis. Pressure over the fifth metatarsal head necessitated its removal. Callosities over neck and base of fifth metatarsal and severe claw toes.

operation to rid them of apparatus they had worn for five years or more. All the men had refused on the grounds that the apparatus was little or no handicap. Women, however, were more conscious of the ugliness of the apparatus and were in favour of operation.

It is evident that for the treatment of sciatic paralysis Lambrinudi's operation is so unreliable that it should be advised only with great caution.

Tenodesis—While it was recognised that tenodesis for foot-drop had been a failure in children, it was considered justifiable to give the operation a trial in adults as a time-saving measure. There was great pressure to return men to military service as quickly as possible. Accordingly, fixation of the tendons of the tibialis anterior and peroneus longus into the tibia was performed in five cases. Only one patient had an excellent result; he even was able to play hockey for two seasons without difficulty. In the others the foot-drop soon recurred and the operation was therefore discarded.

Tendon transplantation—Transfer of the posterior tibial tendon through the interosseous membrane to the dorsum of the foot (Watkins, Jones, Ryder and Brown 1954) has been used in cases of lateral popliteal paralysis. In this series there were four examples of this operation in which the period of post-operative observation was three years or more, and in all four cases the functional result was excellent. There have so far been no failures in twelve subsequent cases. The operation abolished the deforming pull of the tibialis posterior and restored active dorsiflexion of the foot. It is still questionable whether this active dorsiflexion takes place when the patient is walking, but it certainly eliminates the foot-drop. It has yet to be decided whether it is best to attach the tendon to the mid-dorsum of the foot or to the extensors of the toes.

Correction of claw toes—The commonest deformity is the claw toe which was present in one-third of all cases (Figs. 2, 3 and 10). It is usually a consequence of medial popliteal paralysis; in only ten cases—9 per cent—was the lateral popliteal nerve alone affected. It is uncommon after complete nerve lesions. Fifty-four per cent of cases of clawed toes followed incomplete lesions of the medial popliteal nerve; 31 per cent were after nerve suture. Thirteen patients were treated by arthrodesis of the proximal interphalangeal joints and the results were excellent.

In view of the peculiarly disabling consequences of deformity of the more or less anaesthetic foot no time should be lost before incipient deformity is corrected; it is best to intervene before operations involving bone resection become necessary.

Amputation—In the past, amputation was often thought to be the inevitable fate of patients with complete sciatic nerve lesions. This defeatist attitude is unjustified. Ten amputations were carried out on patients in this series. In nine there had been a total sciatic lesion initially. There was no motor recovery in five cases, partial recovery in four, and useful recovery in only one case. Six patients showed no sensory recovery. Satisfactory sensory recovery does not preclude the possibility of amputation but it is less likely to be necessary than in patients with total sensory loss.

Reasons for amputation—These were: 1) stiff foot with fixed deformity (eight cases); 2) pressure sores (seven cases); and 3) pain (five cases—causalgia, one; hypersensitivity, one).

Patients' response to amputation—Five patients were satisfied with the result, three were not and two offered no comment. The patients on whom the operation was carried out for fixed deformity with secondary ulceration were extremely happy. The three dissatisfied patients had undergone amputation for pain and, unfortunately, as might be expected, the pain did not improve. There should, therefore, be little reason for amputation of the leg after sciatic nerve injury. If pain is present it is unlikely to be relieved; with proper treatment from the beginning to prevent stiffness and deformity there should be no reason for amputation on this account.

SUMMARY

1. We have described what happens to patients a number of years after injury of the sciatic nerve or of its divisions; there were 329 who had been under observation for periods ranging from three to eighteen years. The neurological recovery was recorded in every case and, more important, the behaviour of the limb as appreciated by the patient.

2. Although it was generally true that good neurological recovery and good function went together there were remarkable discrepancies. Isolated paralysis of the medial popliteal or of the lateral popliteal nerve was often compatible with good function, though patients with lateral popliteal paralysis usually needed toe-raising apparatus. Even total sciatic paralysis sometimes gave little trouble.

3. Of the various types of injury, clean wounds and traction lesions led to rather better than average return of function.

4. Some degree of pain was present in about half the cases, and over-response—exaggerated and painful response to an ordinary stimulus—was present in one-third of the cases.

5. Repair of the posterior tibial nerve was rarely worth while; no less than eight out of twelve patients with this type of injury exhibited over-response.

6. One-third of the patients showed vasomotor and trophic disorders: coldness of the affected limb, erythema, thinness or pigmentation of the skin, changes in the nails or oedema.

7. Pressure sores were the most serious consequence of sciatic nerve injury and at some time or other were present in 14 per cent of our patients. The cause was deformity rather than insensibility of the sole.

8. Of the various palliative operations Lambrinudi's tarsal arthrodesis gave such disappointing results that we doubt whether the operation is worth doing. Tenodesis, revived as a time-saving expedient during the war, was a failure. For lateral popliteal paralysis anterior transplantation of tibialis posterior is excellent.

9. Amputation was done in only ten cases. When it was performed for fixed deformity with secondary ulceration the result was satisfactory. When it was done because of pain there was no relief. Amputation is, therefore, avoidable provided that vigorous steps are taken to prevent or correct deformity; it should not be done for the relief of pain.

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FAILURE OF UNION IN FRACTURE OF THE NECK OF THE FEMUR

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The treatment of patients with fracture of the neck of the femur is beset by many difficulties, medical and social as well as surgical. Of these difficulties failure of union is perhaps the most common, the most disabling and the most intractable. This paper outlines a hypothesis to explain the incidence of non-union in this and related injuries.

THE HYPOTHESIS

There is within synovial joints a system to preserve the joint cavity after injury. This system works by tending to prevent the coagulation of blood shed into the joint and by rapidly removing, without organisation, any clots that do form. It is suggested that the same system perpetuates the fracture gap in fractures that are wholly intra-articular.

The hypothesis is based on an analysis of the clinical features of the injury, and on two observations on the pathology, observations which have been supplemented by experimental and histological evidence.

THE CLINICAL PROBLEM

Non-union in complete, unimpacted, intracapsular fractures of the neck of the femur presents features not seen in most fractures elsewhere. Non-union is exceptionally common at this site. With treatment by nailing it has been reported in up to 50 per cent of cases (Eyre-Brook and Pridie 1941; Charnley, Blockey and Purser 1957). In a series of forty-one patients personally reviewed (Table I) non-union was clear in 37 per cent and suspected in a further 12 per cent.

TABLE I

RESULTS OF NAILING: ANALYSIS OF FRACTURES OF THE NECK OF THE FEMUR TREATED AT ST MARY'S HOSPITAL 1950–55

Total number of patients	**52**	
Died within five weeks of injury	5	
Lost to follow-up	6	
Patients for review	**41**	
Fracture failed to unite	15	(37 per cent)
Walking with pain (2, 2, 7, 8 and 13 months later)	5	(12 per cent)
Satisfactory when last seen (average follow-up 11 months)	21	(51 per cent)

Preoccupation with the failure of many of these fractures to unite when treated has perhaps led to the more important question being overlooked—that is, the reason for the universal failure of union in untreated fractures. This injury is distinguished from other fractures by never uniting spontaneously—that is, when the patient is treated by simple rest of the injured limb in bed. Union is entirely dependent upon specially skilled treatment. There is nothing to make us suppose that non-union in treated cases has a cause different from that responsible for the non-union of untreated cases.

In general, experience has shown that when the fracture is treated by internal fixation, if reduction is incomplete, union is not likely to follow (Lloyd 1938; Lewis, Boutelle and Roberts 1950; Cleveland and Fielding 1954). Imperfect reduction, which in most other fractures leads only to union in bad position, here is apt to produce complete failure of repair. Although small flaps of periosteum are sometimes caught between the fragments (Groves 1927, personal observations) the small amount of tissue available is never likely to constitute a serious barrier to reduction or union.

The successes so far obtained have been achieved by strictly immobilising the fragments. Partial immobilisation, as by traction in a Thomas's knee splint, although sufficient for trochanteric fractures and those of the shaft of the femur, is not enough for fractures of the neck of the femur: union here depends to an unusual degree on the strictness of immobilisation.

When non-union is manifest in spite of treatment, it commonly presents as a complete replacement of the fragments, very unlike the doubtful mobility of the ununited fracture of the shaft of a long bone. Finally, fractures of the neck of the femur, especially when union has failed, may show a remarkable " absorption " of bone from the two fracture surfaces, so that in time the femoral neck disappears.

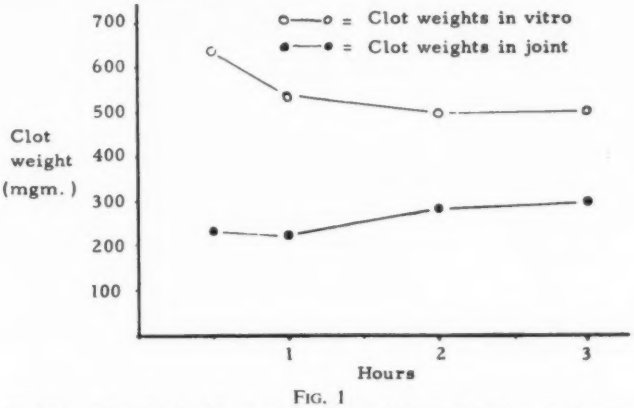

FIG. 1

Weights of clot obtained from one millilitre of blood allowed to clot *in vitro* (*upper curve*), and after injection into a joint (*lower curve*). Siliconed tubes with added thromboplastin were used for the series *in vitro*.

THE BEHAVIOUR OF HAEMARTHROSES

The first observation on the pathology concerns the fluid nature of blood shed into synovial joints. In clinical experience, although clots do sometimes form, such blood is usually found to be fluid. It may be aspirated and it flows out of the joint when it is opened at operation. Any clots that do form tend to disappear within a few days. Why this is so is not yet fully understood.

A short survey made in man showed, in nineteen joints explored within one week of injury, soft clots floating free or attached to injured surfaces in only nine. The clinical impression that there is a defect of coagulation has been supported by evidence from animal experiments, work which will be reported in detail elsewhere.

Comparison was made between the weight of clot formed from a standard volume of blood *in vitro* and after injection into the knee of a rabbit. The results are shown in Figure 1. The weights of clot formed in the joint were about half those obtained *in vitro*. Experiments performed in dogs showed a similar deficiency in the volume of clot formed (Table II).

Examination of the fluid component of experimental haemarthroses in the rabbit produced no evidence to suggest the presence of an anticoagulant (no increased concentration of

antithrombin compared with that of defibrinated rabbit plasma). The haemarthrosis fluid was found to be unclottable because it was devoid of fibrinogen. Examination of human haemarthrosis fluid gave the same findings.

TABLE II

EXPERIMENTAL HAEMARTHROSES IN DOGS

Haemarthroses induced by injection	**17**
No clot found*	3
Small clots	10
More than a quarter volume clotted	3
More than half volume clotted	1
Haemarthroses induced by drilling across the joint	**8**
No clot found	8

* The joints were explored at intervals of from five minutes to six hours after induction of the haemarthrosis.

When citrated plasma was injected into a rabbit knee the fibrinogen level of the fluid in the joint fell to zero within one and a half hours although very little or no clot was discoverable

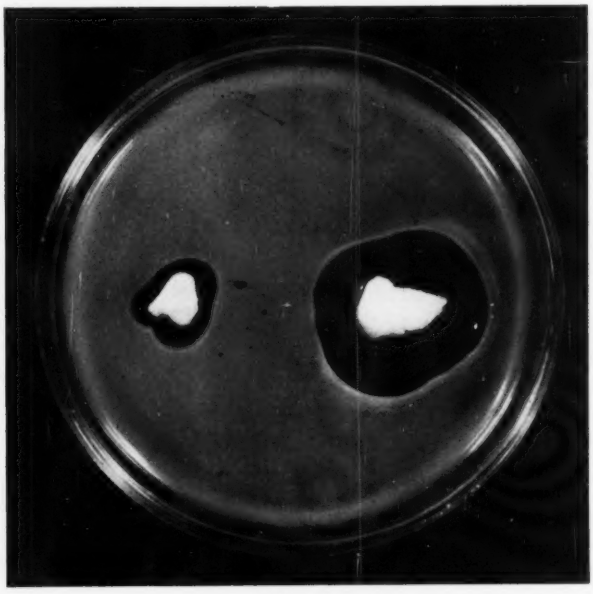

FIG. 2

A Petri dish containing a fibrin clot on which has been laid a piece of synovial membrane (*right*), and a piece of articular cartilage (*left*). After eighteen hours' incubation a zone of lysis of the clot has appeared around both tissues.

on opening the joint. With heparinised plasma no such fall in fibrinogen concentration occurred.

It has been realised for many years (Fleisher and Loeb 1915) that many tissues have the power to break down plasma clots. This property has been shown (Astrup and Permin 194

Goldhaber, Cornman and Ormsbee 1947) to be due to the release of activators from the tissue concerned, substances which convert the pro-enzyme plasminogen in the plasma into the active protease, plasmin. The release of activator from articular cartilage (Lack 1959) and synovial membrane is readily demonstrable (Fig. 2). Plasmin will act on many substrates, fibrinogen as well as fibrin. Heparin is in most circumstances an inhibitor of plasmin. The disappearance of fibrinogen from citrate plasma but not from heparin plasma in a joint could thus be explained by the action of plasmin. It is indeed possible that both the deficiency of clot formation and the rapid disappearance of clots that do form in joints are caused by the physiological activation of plasmin by the joint tissues.

The absence of lasting clot in synovial joints prevents the formation of granulation tissue and so preserves the joint space and movement after injury.

NON-UNION IS COMPLETE

The second basic observation is that non-union in fracture of the neck of the femur is complete. No reparative tissue is found bridging the fracture gap (Fig. 3). This was noted by Santos (1930) and by Sherman and Phemister (1947), but its significance was not emphasised. The failure of repair involves fibrous tissue as well as bone. The twelve specimens in the present study in which there had been clinical failure of bony union all showed absence of fibrous union as well, although a proliferative tissue response was visible on one or both sides of the fracture gap. The only exception to this finding was the relatively late development of intra-articular adhesions, binding all structures in the joint together.

The completeness of non-union accounts for the complete redisplacement seen when osteosynthesis fails. It suggests that the failure of repair occurs at or before the stage of organisation of the fracture haematoma.

FIG. 3

An ununited fracture of the neck of the femur. The fragments are connected only by the soft-tissue hinge at the back.

HISTOLOGICAL EVIDENCE

Material from twenty-three patients with a fractured neck of femur was studied. In addition twelve recent fractures were explored at open operation. Comparison was made with material from selected fractures elsewhere.

On the first day the hip joint is distended by a viscous, bloody fluid. The fracture surfaces may be bare or covered by a thin layer of clot. Clot was generally absent by the fourth day in untreated fractures. From then on the fracture surfaces were covered only by debris (Figs. 4 and 5). Towards the end of the first week proliferation of cells was visible in the tissues next to the fracture. New bone could be seen by the end of the second week. The proliferating cells extended up to the stumps of the broken trabeculae, only occasionally extending farther as a fringe of granulation tissue.

The specimens from all twelve patients with established clinical non-union showed widespread necrosis of the bone of the femoral head. In only six, however, did the sections examined show complete, or almost complete, necrosis of the marrow as well.

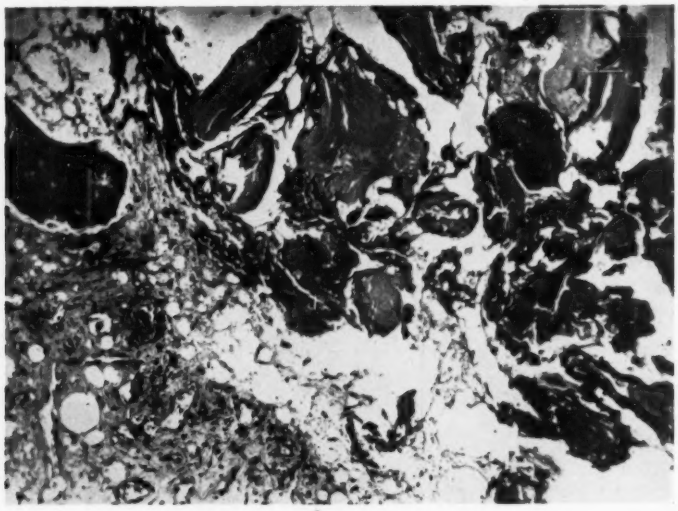

FIG. 4

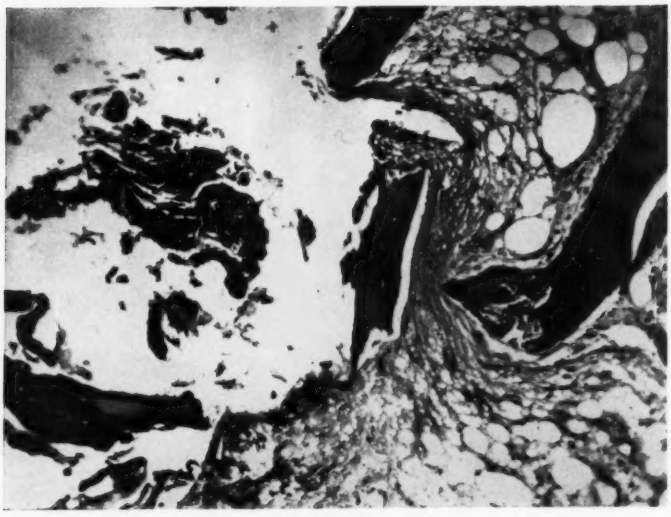

FIG. 5

The fracture surfaces from a fractured neck of femur eighteen days old. In both the proximal fragment (Fig. 4) and the distal fragment (Fig. 5) the surfaces are covered only by debris. The space between is filled by the effused fluid.

Bone necrosis was also seen regularly in the distal fragment, affecting the cortex more than the cancellous medulla.

Absorption of both fracture surfaces was seen even when the proximal fragment was completely ischaemic. Absorption thus seems to be independent of vascular and tissue

responses at the fracture line. The macroscopic and histological appearances suggested rather that it was caused by simple friction between the fragments—friction allowed by the absence of fibrous union.

In a recent, well reduced femoral neck fracture the gap was found to be filled by a continuous clot, broken only by vacuoles of serum or fat, and containing fragments of bone debris. In a uniting fracture two months old a little unorganised clot was still present in the narrow gap, which was elsewhere bridged by callus (Fig. 6).

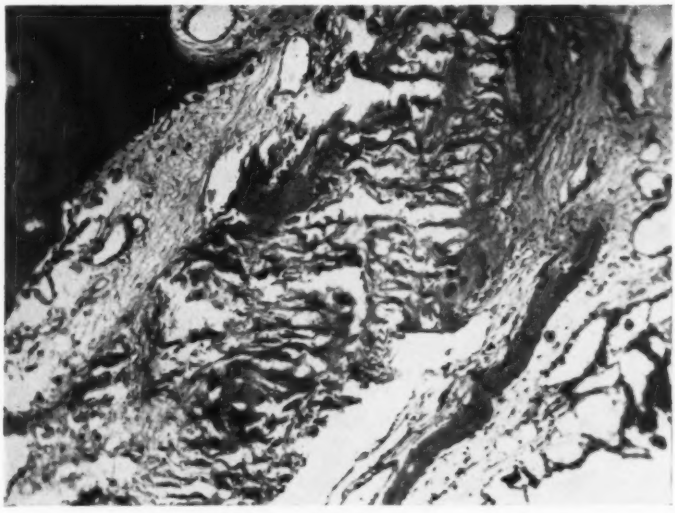

FIG. 6
A narrow zone of thrombus uniting the fragments of an adequately treated fracture of the neck of the femur two months after the injury. Elsewhere the fracture was united by young bone and connective tissue.

DISCUSSION

Union of fractures of the femoral neck occurs by direct adhesion of the bone ends, by the migration of cells from one fracture surface to the other, across the fracture gap. These cells cannot swim. To move they crawl, and they must have something solid to crawl upon (Harrison 1914, Abercrombie 1957). If the gap between the bone ends is filled by fluid (the unclotted joint effusion) it cannot be bridged by proliferating cells from either fragment. Non-union is complete.

Union can occur only if the fracture is closely reduced, so that the fracture surfaces are once more in contact, or at least so close that the gap between is filled by the thin layer of clot on the bone ends. Immobilisation must be strict so as not to break this fragile fibrin bridge over which the reparative cells migrate.

If, as may happen, the head fragment dies from damage to its blood supply, union can occur with almost equal facility by proliferation of cells from only one side of the gap, in the same way as an autogenous bone graft unites with the living bone against which it lies.

In extra-articular fractures conditions for union are less exacting. If the fracture is strictly immobilised from the start, the fracture haematoma may be rapidly organised and replaced by callus (Fig. 7). The clot between the fragments, however, is often broken up by movement, so that the bone ends lie in a cavity containing serous fluid. Union by first intention, by direct adhesion between the fracture surfaces, then cannot occur. The fracture unites instead by second intention. From the soft tissues surrounding the fracture haematoma a

layer of granulation tissue and callus forms (Fig. 8). This layer thickens and gradually obliterates the fracture cavity by proliferation from the periphery (Urist and Johnson 1943, Charnley 1957).

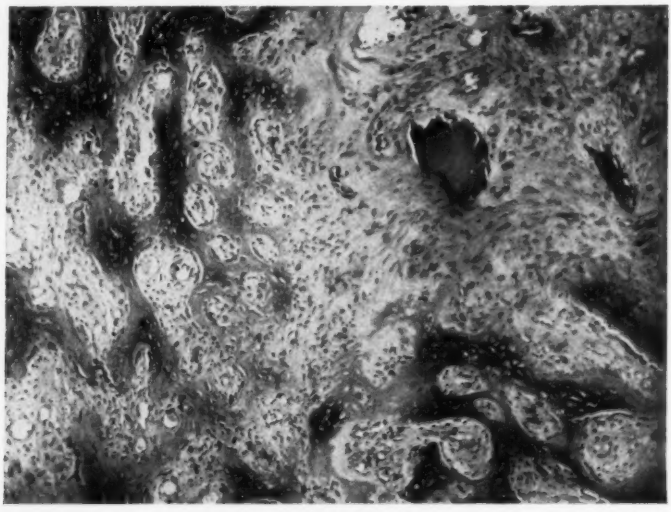

FIG. 7

Callus from a fractured shaft of tibia nineteen days old. The bone debris visible indicates that the callus has replaced the original fracture haematoma.

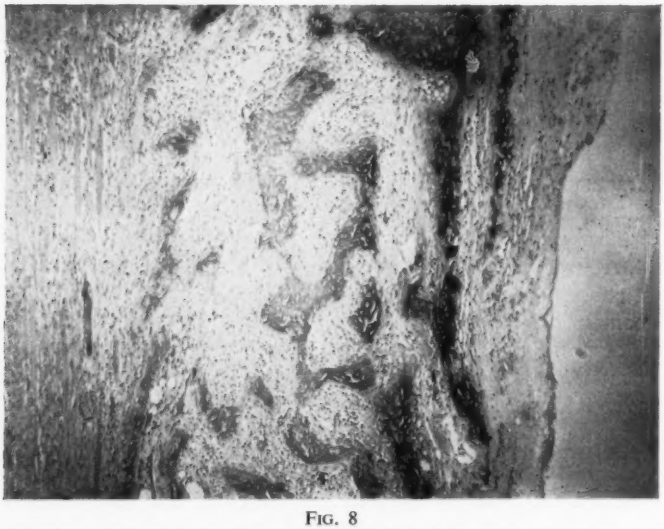

FIG. 8

The wall of the haematoma from a fractured shaft of humerus sixteen days old. From without in, muscle fibres, callus and granulation tissue can be seen.

Similar healing by second intention can occur in fractures exposed to a joint on one side, the fracture gap being filled by proliferation of tissues from its non-articular sides. Healing by second intention, however, cannot occur when a fracture is exposed to a joint on two

opposing sides. Union then depends upon primary adhesion of the fracture surfaces which demands close reduction and complete immobilisation.

Other intra-articular fractures.—These circumstances occur in two other important fractures, the behaviour of which lends support to the hypothesis.

The waist of the scaphoid bone is exposed on two sides to synovial joint (Fig. 9). Fractures here share with those of the femoral neck the distinction of rarely uniting without treatment.

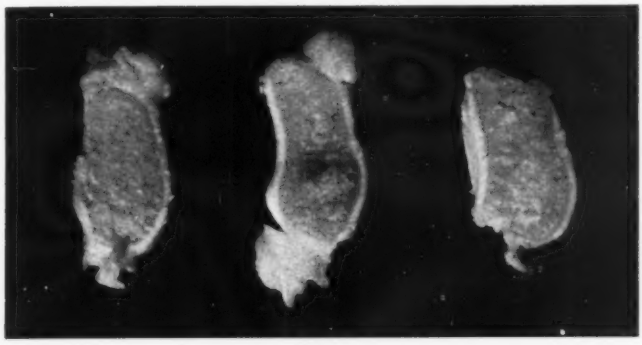

FIG. 9

Three slices across the waist of the scaphoid showing the extent of the articular surfaces. The most proximal slice is to the left.

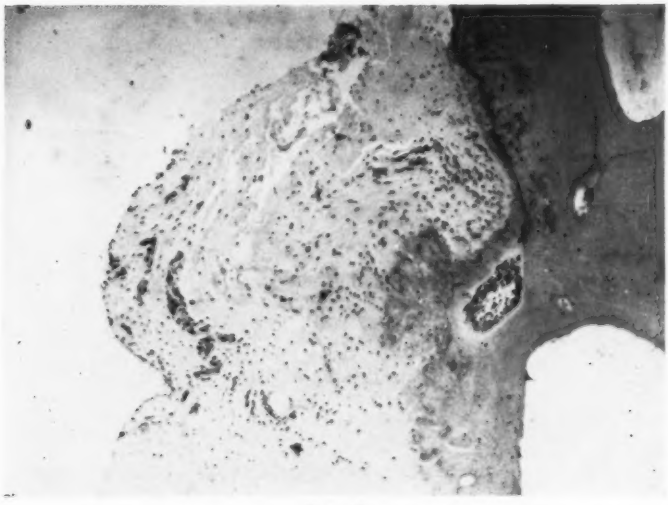

FIG. 10

Fibrous tissue lining the gap in an ununited fracture of the waist of the scaphoid: from the proximal fragment, twelve months after injury.

An apparently trivial crack has to be most strictly immobilised to secure union. Non-union, when it occurs, is absolute (Fig. 10). In recent fractures unclotted blood has been seen flushing the fracture gap (McLaughlin 1954).

Oblique fracture across the base of the lateral humeral condyle is almost the only fracture in children in which non-union is a problem. The importance of exact reduction and firm fixation has recently been emphasised (Jeffery 1958). When union fails, the fracture is

completely ununited in its lower part (Cooper 1822). Oblique section of the lower end of the humerus shows the intra-articular position of most of the fracture line (Fig. 11).

CONCLUSIONS

The hypothesis provides a theoretical justification for, and re-emphasises the practical importance of, close reduction and strict immobilisation in the treatment of fractures of the neck of the femur. It does not support the view that failure of union is caused by vascular damage at the time of the original injury. Unexpected failure of union after nailing is more likely caused by unrecognised imperfection of reduction and the acknowledged deficiencies of internal fixation.

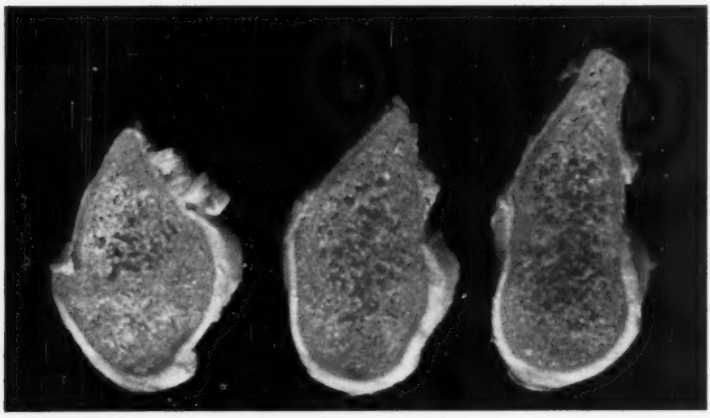

FIG. 11
Oblique slices across the base of the lateral humeral condyle, to show how fractures in this plane are partly intra-articular.

Attempts to improve results by passing the sartorius muscle around the fracture (Adams 1956), or by attaching muscle or joint capsule to the proximal fragment, have failed, because such soft tissues are swept off by the acetabular rim when the hip is flexed or medially rotated.

Further work is required, both on the more detailed biochemistry of haemarthroses and on the practical and wider implications of the hypothesis.

Mr J. Crawford Adams first called my attention to the possible role of the synovial fluid, and gave freely of help and encouragement in the development of the hypothesis. To him and to Mr G. L. W. Bonney I am very grateful for much excellent advice and for permission to report on their patients.

Dr C. K. Simpson and Mr B. Peirard helped in the collection of specimens. I am grateful to the Pathology Department of St Mary's Hospital for the histological preparations.

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SIMULTANEOUS BILATERAL FRACTURES OF THE NECK OF THE FEMUR

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The purpose of this paper is to report a series of severe simultaneous bilateral hip injuries occurring during convulsions, and to review the previous reports of similar simultaneous bilateral injuries from convulsions and from other causes. The injuries have comprised bilateral fractures of the necks of the femora, bilateral central dislocations of the hips and fracture of one femoral neck with simultaneous central dislocation of the other hip. All the cases—observed or collected—are summarised in Tables I to III.

Such injuries may occur as a result of accident, of local destructive disease, or of convulsions, epileptic or induced.

FIG. 1

Case 31—An elderly patient suffering from rheumatoid arthritis was treated with phenylbutazone. While she was under treatment these fractures occurred.

Accident, assuming the term to indicate violent injury to normal structures, is rare as a cause of these combined lesions. As Speed (1953) pointed out, simultaneous bilateral traumatic hip dislocation is rare; simultaneous fractures of the femoral necks appear to be considerably rarer. Although I have been given brief details of two such cases occurring during the second world war, I have been unable to trace any reported cases except those of Konforti and Chokanov (1956) and Carrell and Carrell (1941) (Cases 27 and 28).

Simultaneous major bilateral hip injuries in the presence of disease of the femoral neck or acetabulum were reported by Dohrmann (1953) and Stewart (1957). These cases, mentioned in Table II (Cases 29 and 30), were instances of fractures discovered during the investigation of general disease. In both cases there is a well justified assumption that the injuries were simultaneous, though conclusive proof is lacking. I am indebted to Mr R. S. Garden for details of a third case (Case 31), that of a woman suffering from severe rheumatoid arthritis treated by phenylbutazone (Fig. 1).

I have found no record of simultaneous bilateral central dislocation of the hip in consequence of local disease, and, although both femoral necks are often fractured in patients suffering from secondary malignant deposits or from senile osteoporosis, I have not found an instance of such fractures occurring simultaneously.

The commonest cause of these simultaneous injuries is some form of convulsion. The danger of fractures in major epileptic fits has not long been recognised, and the occurrence of double injuries has drawn little attention. Two simultaneous bilateral femoral neck fractures previously reported are included in Table II (Cases 32 and 33), and I am grateful to Dr. P. Hoffmann for details of another, unreported patient (Case 20). I have not found any record of central dislocation from non-therapeutic epileptic fits.

Pharmacological convulsive therapy was first introduced by Meduna (1935), and reports of bilateral femoral neck fractures complicating this treatment began to appear three years later. I have not found a report more recent than 1944 (Pereira da Silva and Ferreira de Barros).

Electroconvulsive therapy was introduced by Cerletti and Bini (1938). This method of treatment has largely, if not entirely, replaced pharmacological convulsive therapy. Most of the published instances of double injuries occurred after this treatment, and almost all the patients whose details I have collected sustained their injuries from electroconvulsive therapy.

CASE REPORTS

SIMULTANEOUS BILATERAL FRACTURE OF THE FEMORAL NECK

Case 1—A man aged fifty-seven was admitted to the Prestwich Mental Hospital in June 1956 with delusional psychosis. Three electroconvulsive treatments were given without the use of anaesthesia or muscle relaxants, and without complications. After the fourth treatment, during which no crack was heard, he was unable to move his legs and he complained of pain in both thighs. He was transferred to the Salford Royal Hospital, and was found to have the

FIG. 2

Case 1—Bilateral femoral neck fractures in a man of fifty-seven who was having electroconvulsive therapy, unmodified by anaesthesia or relaxant drugs.

injuries shown in Figure 2. Radiographs also showed crush fractures of the bodies of the fifth and sixth thoracic vertebrae, though there was no complaint of pain in that region.

Under general anaesthesia both hip fractures were reduced by manipulation. This required considerable force. Compression screws (Charnley, Blockey and Purser 1957) were inserted first on the left side and then on the right. Post-operative ileus lasting thirty-six

TABLE I

ANALYSIS OF PREVIOUSLY UNREPORTED CASES

Case number	Method of production	Sex	Age	Psychiatric diagnosis	Time in mental hospital	Treatment number	Whether modified	Orthopaedic treatment	Result	Comments
Part 1. Simultaneous bilateral femoral neck fractures										
1	Electroconvulsive therapy	M	57	Psychosis with delusions	3 weeks	Fourth	No	Two compression screws inserted at one operation	Good functional result at 2½ years	
2	Electroconvulsive therapy	M	30	Schizophrenia	5 months	Fourth in second series	No	Two compression screws inserted	Walking with crutches two years later	Initial reduction of left fracture impossible, and two further operations were necessary for this fracture. Bilateral septic arthritis developed
3	Uraemic convulsion	F	53	Vague six-year history of renal trouble with recent vomiting and oedema of the legs. Blood urea 228 milligrams/100 millilitres. Bacterium coli urinary infection. After admission condition varied between acidosis and tetany, with very low serum calcium. Twelve days after admission had a convulsion while in bed. Became disorientated thereafter, but complained of pain in both thighs. Radiographs revealed bilateral subcapital fractures						See text
4	Electroconvulsive therapy	F	59	Depression	4 days	Third	No	Both nailed	Satisfactory	Given further modified electroconvulsive therapy without trouble
5	Electroconvulsive therapy	F	55	Post-encephalitic psychosis	4 years	First	No	Traction	Remains in bed	Patient bedridden before treatment started
6	Electroconvulsive therapy	M	56	Chronic schizophrenia	4 years	Fourth in second series	No	Both nailed	Union. Left leg 1 inch short	Ectonus Rheostat machine used. There was momentary power failure and machine switched off and on, producing a violent jerk
7	Electroconvulsive therapy	M	67	Arterio-sclerotic dementia	2½ years	First	No	Nil	?	Same as Case 6
8	Electroconvulsive therapy	M	72	Senile				Both nailed in two	Not walking	

7	Electroconvulsive therapy	M	67	Arterio-sclerotic dementia	2½ years	First	No	Nil	?	Same as Case 6
8	Electroconvulsive therapy	F	71	Senile depression	1 year	First	No	Both nailed in two operations. Left not perfect; left hip spica	Not walking.	
9	Electroconvulsive therapy	M	35	Catatonic schizophrenia	6 months	Third maintenance dose; many electroconvulsive therapies before	No	Both nailed. Not easy. Not perfect	Walks quite well in mental hospital	
10	Cardiazol	M	39	Paranoid schizophrenia	6 months	First	No	Double hip spica	Gets about fairly well	
11	Electroconvulsive therapy	F	58	Chronic depression	13 years	First	No	Both nailed	Gets about fairly well	
12	Electroconvulsive therapy	F	?	Chronic schizophrenia	?	?	No	Left nailed. Right prosthesis. Later left osteotomy	Died two years later from uraemia	
13	Electroconvulsive therapy	M	26	Schizophrenia	2 years	First	No	All attempts at closed reduction unsatisfactory. Spica	Union. Walking quite well	
14	Electroconvulsive therapy	M	50	Depression	20 years	Fourth	No	Reduction impossible. Both nailed in fair position	Died of chronic septicaemia eight months after fractures	Paget's disease. Further modified electroconvulsive therapy three months later
15	Electroconvulsive therapy	M	35	Schizophrenia	10 years	Third	No	Left nailed. Right spica	Walked with difficulty	Died three years later from volvulus of colon
16	Electroconvulsive therapy	M	34	Schizophrenia	9 years	Third	No	Left nailed. Right spica. Right osteotomy one month later	Still in hospital. Gets about fairly well	
17	Electroconvulsive therapy	F	53	Chronic melancholia	20 days	Fourth	No	Both nailed in one session. Right prosthesis four days later	Still in hospital. Fully ambulant with one stick	
18	Electroconvulsive therapy	F	34	Schizophrenia	8 years	Fifth of present series	No	Conservative		
19	Electroconvulsive therapy	M	33	Agitated depression	Out-patient	Third	No	Both nailed at one session	Right not fully reduced. Walks fairly well with some aching	
20	*Grand mal* convulsion	M	?	Convalescent soldier with gunshot wound of head. Nailed at two sessions. Fractures healed						

TABLE I—*continued*

Case number	Method of production	Sex	Age	Psychiatric diagnosis	Time in mental hospital	Treatment number	Whether modified	Orthopaedic treatment	Result	Comments
Part 2. Simultaneous bilateral central dislocations of the hip										
21	Electroconvulsive therapy	M	61	Recurrent depression	2 days	Fifth	No	Bed and chair rest; then physiotherapy	Full functional recovery	Hypochondriacal. Given seventeen more treatments, modified, with no trouble
22	Electroconvulsive therapy	M	54	Depressive state	2 days	Second	No	Extension for some weeks then physiotherapy	Fair	
23	Electroconvulsive therapy	F	49	Catatonic schizophrenia	17 years	First	No	Open operation	Can just walk	
24	Electroconvulsive therapy	M	40	Paranoid schizophrenia	Out-patient	Second	No	Traction for ten days. Attempted reposition from inside pelvis failed; traction for eight weeks	Walks fairly well with some pain	
25	Electroconvulsive therapy	M	63	Reactive depression	?	Third	No	Conservative		Chronic alcoholism
Part 3. Simultaneous central dislocation of one hip, with fracture of the contralateral femoral neck										
26	Electroconvulsive therapy	M	41	Schizophrenia	5 years (third time)	Twenty-first of present series	No	Right nailed. Left skeletal traction.	Left better than right	

Note: The injuries of Case 23 are shown in Figure 7, those of Case 26 in Figures 8 and 9, and Figure 10 shows the two hips of Case 16 nine years after injury and operation.

TABLE II

TABLE II

PREVIOUSLY REPORTED BILATERAL INJURIES NOT DUE TO THERAPEUTICALLY INDUCED CONVULSIONS

Case number	Year	Author	Diagnosis	Method of production	Sex	Age	History of injury and details of treatment	Result	Comments
27	1956	Konforti and Chokanov	Bilateral neck fracture	Accident	M	37	Miner, crushed by fall from pit roof. Plaster spica applied and patient sent to Sofia for radiograph. Three and a half weeks' traction. Operation under local anaesthesia, two teams working simultaneously. Right nail, left Putti screw	Not stated	Used a circular portable radiograph tube, placed between the legs, and easily rotated from one side to the other
28	1941	Carrell and Carrell	Bilateral neck fracture	Accident	M	8	Fell 25 feet from a tree. Treated by reduction, traction in abduction, tenotomy of adductors and fixed skeletal traction for eight weeks	Union. Good function at eighteen months	
29	1953	Dohrmann	Bilateral neck fracture	Disease of the femoral neck	M	32	Scarlet fever was complicated by left renal abscess. Patient suffered leg cramps when trying to stand, lost consciousness; in hospital radiographs revealed bilateral fractures. Pyelonephritis, bilateral hydro-ureter and left hydronephrosis ensued. The right fracture was nailed, and traction was applied to the left leg. Four months later the left fracture was nailed, and the right operation having been unsatisfactory, a new right-sided nailing was done	Not stated	
30	1957	Stewart	Bilateral neck fracture	Disease of the femoral neck	M	41	A diabetic with active pulmonary tuberculosis, who complained of pain in both hips for some weeks. There was no history of injury, coma or convulsions. Radiographs showed displaced bilateral femoral neck fractures. Treatment by traction in bed produced a satisfactory result	Walked well	See Figures 11 and 12
31	1957	Garden	Bilateral neck fracture	Disease of the femoral neck and acetabulum	F	?	Patient with severe rheumatoid arthritis. Treated with phenylbutazone. Referred some time after the fractures had occurred	Intertrochanteric osteotomy on one side	See Figure 1
32	1956	Andreini	Bilateral neck fracture	Epileptic	M	68	After a head wound in the 1915–18 war he developed a syndrome with cerebellar disorder, and lived in bed or in a chair. After a severe fit there was pain in both hips. Radiographs six weeks later showed bilateral fractures but normal bone structure. A nail was inserted on the right side. Then he developed acute appendicitis, and after recovery from this it was too late to nail the left side	Not stated	
33	1953	Dhanik	Bilateral neck fracture	Epileptic	M	34	A known epileptic had been one year under treatment for pulmonary tuberculosis. After a *grand mal* seizure there was pain in the right groin, and the same evening after another fit there was pain in the left groin	Conservative treatment	

TABLE III

BILATERAL INJURIES FROM THERAPEUTICALLY INDUCED CONVULSIONS; CASES PREVIOUSLY REPORTED IN THE LITERATURE

Year	Author	Diagnosis	Method of production of convulsions	Sex	Age	Psychiatric diagnosis	Time in mental hospital	Treatment number	Whether modified	Orthopaedic treatment	Result	Comments
Part 1. Bilateral femoral neck and intertrochanteric fractures												
1938	Satta	Bilateral neck fracture	Cardiazol	M	36	Dementia praecox	5 years	Many previous treatments	No	?	?	Radiologically normal bone
1938	Pameijer	Bilateral neck fracture	Metrazol	Quotes three cases but gives no details								
1938	Walk and Mayer-Gross	Bilateral neck fracture	Triazol	M	35	Schizophrenia	4 years, mostly in bed	First	No	One month later to general hospital; bilateral osteotomy	Died ten hours after operation	No evidence of bone disease
1939	Le Guillant	Bilateral neck fracture	Cardiazol	Two patients, bedridden for several years; no details given								
1939	Somers and Richardson	Bilateral neck fracture	Cardiazol	M	31	Schizophrenia	?	Second convulsion, ninth injection	No	Traction in bed. Two weeks later bilateral nailing. Weight bearing at twelve weeks	?	Seizure lasted three minutes
1940	Cummins	Bilateral neck fracture	Metrazol	?	?	Schizophrenia	8 years	Fourth	No	?	?	Very inactive patient. Not emaciated
1940	Gissane, Blair and Rank	Bilateral neck fracture	Cardiazol	M	40	?	?	Fifth	No	Skeletal traction. Right needed further manipulation. Two nails inserted. Revision of right operation at four weeks with graft added	Good at three months	The second case reported by Gissane, Blair and Rank is that of Walk and Mayer-Gross
1940	Nielsen and Ingham	Bilateral neck fracture	Metrazol	F	53	Paranoid psychosis	3 months	First	No	Nil	Death in four days	Fat embolism
1941	Androp	Bilateral neck fracture	Metrazol	M	43	?	20 years	Third	No	Nil	Bad result attributed to extreme negativism	Injuries occurred in November 1937
1941	Krause and	Bilateral		M	31	Paranoid	?	Third	No		?	

1941	Androp	Bilateral neck fracture	Metrazol	M	43	?	20 years	Third	No	Nil	Bad result attributed to extreme negativism	Injuries occurred in November 1937
1941	Krause and Scherb	Bilateral neck fracture	Metrazol	M	31	Paranoid schizophrenia	?	Third	No	Bilateral nailing	?	
				M	31	Schizophrenia	?	First	No	Bilateral nailing		
1943	Samuel	Bilateral neck fracture	Electroconvulsive therapy	No details given								
1944	Pereira da Silva and Ferreira de Barros	Bilateral neck fracture	Cardiazol	M	39	Hebephrenic schizophrenia	?	4 injections 4 crises	No	?	Died	Reduction difficult
				M	26	Hebephrenic schizophrenia	?	8 injections 5 crises	No	?	Died	Union delayed
				M	35	Hebephrenic schizophrenia	?	1 injection 1 crisis	No	?	Alive	Complications frequent
1947	Santagati	Bilateral neck fracture	Electroconvulsive therapy	F	?	?	?	First	No	?	?	
1950	Meschan, Scruggs and Calhoun	Bilateral intertrochanteric fracture	Electroconvulsive therapy	M	No other details given							
1954	Kelly	Bilateral neck fracture	Electroconvulsive therapy	M	39	Mentally backward	3 months	First	No	Nil	Died in twenty-four hours	Postmortem report: Acute pulmonary oedema. Necks driven hard into femoral heads
1956	Marshall, Donaldson and Shirvaiker	Bilateral neck fracture	Electroconvulsive therapy	M	50	Depressive hypochondriasis	2 weeks	Second	No	Nailing on separate occasions. Walked at six months	Walked fairly well	Left fracture not well reduced
Part 2. Bilateral central dislocations of the hip												
1939	Ligas	Bilateral central dislocation	Cardiazol	F	25	Schizophrenia	4 months	First	No	Traction on Kirschner wires through greater trochanters. Wires removed at ten weeks. Walked at twelve weeks	Good	
1947	Lingley and Robbins	Bilateral central dislocation	Electroconvulsive therapy	Three patients, no details given								
1952	Kalinowsky and Hoch	Bilateral central dislocation	Electroconvulsive therapy	Two cases, but no details given								

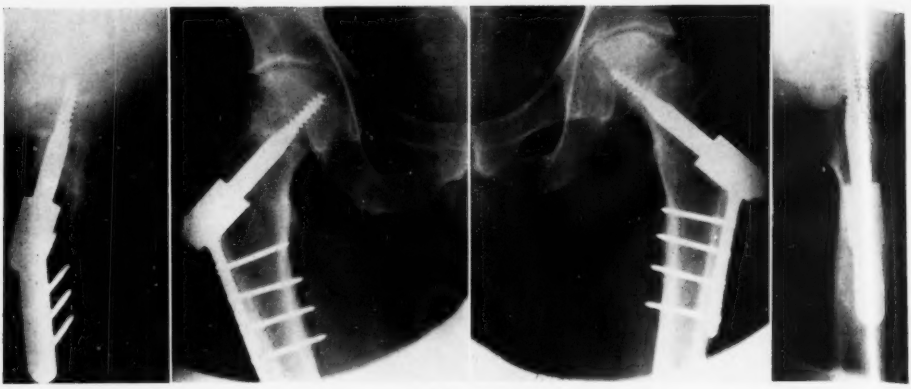

FIG. 3

Case 1—Antero-posterior and lateral radiographs showing the state of the hips two and a half years after the insertion of compression screws. Delayed avascular necrosis is occurring on the left side.

hours responded well to continuous intravenous infusion and gastric suction. Weight bearing was started at three months, and after six months he could walk upstairs unaided. Two and a half years after operation (Fig. 3) he was in good general health and able to walk almost normally. Hip movements were a little restricted.

Case 2—A man aged thirty was admitted to the same mental hospital in August 1956 suffering from schizophrenia. Two electroconvulsive treatments were followed by a course of fifty insulin comas and a further course of electroconvulsive therapy. The injuries were sustained during the fourth treatment of the second series of electroconvulsive shocks, which were given without anaesthesia or relaxants. On transfer to the Salford Royal Hospital in December 1956 he was in severe pain. The injuries are shown in Figure 4; the extent to which the femoral necks are driven into the femoral heads is noticeable.

FIG. 4

Case 2—Bilateral femoral neck fractures occurred in a man of thirty who was having electroconvulsive therapy, unmodified by anaesthesia or relaxant drugs.

FIG. 5

Case 2—Antero-posterior radiograph showing the state of the hips one year after the insertion of compression screws. Bilateral septic arthritis had ensued, and both screws had been removed.

Under general anaesthesia both hips were manipulated. It was possible to reduce the fracture on the right side, and a compression screw was inserted. The left fracture could not be disimpacted, even after the exposure had been made, so it was decided to abandon further attempts. The wound was closed and skeletal traction was applied through the upper end of the tibia. A week later further radiographic examination showed adequate disimpaction of the left fracture, and three days later the wound was reopened and a compression screw was inserted. This had to be reinserted later on account of slipping of the screw. The wounds both on the right and left sides became infected, and there were massive deep thromboses in both legs. Eventually both compression screws were removed. Flexion contractures developed in both knees and serial wedged plasters were required to correct them. Radiographs taken in January 1958 showed that both femoral necks and heads had been absorbed (Fig. 5). Eight months later graduated walking instruction was begun, but he faces the future with two destroyed hip joints and considerable stiffness in both knees.

Case 3—A woman aged fifty-three was admitted to the Manchester Royal Infirmary in February 1959 for investigation of uraemia and pyelonephritis. Twelve days after admission she had a sudden " attack," with stertorous breathing, cyanosis and contraction of forehead muscles. Immediately afterwards she lay flat in bed refusing to move either leg; she complained of pain in both thighs and was irrational and disorientated. She was unable to get out of bed and her condition deteriorated. Five days after this " attack " radiographs showed bilateral subcapital fractures (Fig. 6), with considerable displacement on both sides. Because of her poor general condition surgical treatment in this patient was considered inadvisable.

PREVIOUSLY UNREPORTED CASES

As a result of inquiries to eighty of the largest mental hospitals in this country, and of appeals in the medical press, I have been able to collect details of seventeen cases of simultaneous bilateral femoral neck fractures. All but one of these injuries were sustained during convulsion

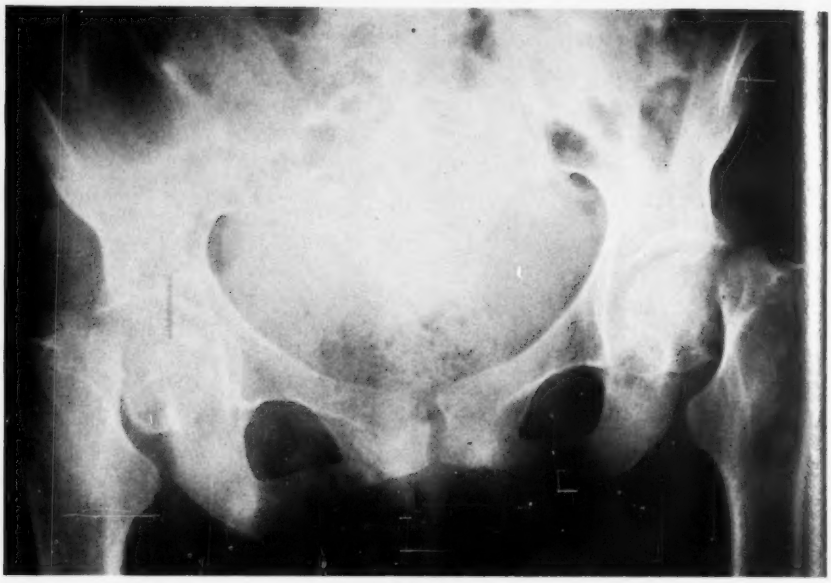

FIG. 6

Case 3—Bilateral femoral neck fractures occurred in a woman of fifty-three during a convulsion in bed, while under investigation for uraemia and pyelonephritis.

FIG. 7

Case 23—Bilateral central hip dislocations occurred in a woman of forty-nine who was having unmodified electroconvulsive therapy.

therapy. Details of these seventeen cases are given in Table I, fifteen of them being from this country, one from Hong Kong and one from the United States of America. I do not believe that this is a complete list of these cases in this country during the last twenty years.

Sex—In Table I are details of twelve men and eight women; this male predominance is in agreement with the figures shown for recorded cases in Table III.

Age—The age of the patients varied between twenty-six and seventy-one; no adult age group is exempt and none is significantly dominant.

Deaths—Two patients (Cases 12 and 14) died from complications following these injuries, the seriousness of which is further shown by the number of deaths reported by previous authors (Table III).

Time in mental hospital—The time spent in hospital by any patient before the injuries occurred varied widely. Some patients had already spent years in hospital, others only a few days, and one was an out-patient. This does not support earlier suggestions that these injuries were most likely to occur in patients long resident in a mental hospital. Two-thirds of the patients sustained their injuries during the first three convulsive treatments. In a few the injuries occurred later during a prolonged course of treatment. The highest incidence of injury was during the first treatment; this does not support Kelly's findings (1954).

Meduna and Friedman (1939) suggested that these injuries were more likely to occur in elderly patients long incarcerated in a mental hospital, long confined to bed, and lacking both normal exercise and an adequate diet. The analysis of these cases does not support these suggestions, and both my male patients were physically fit, neither long confined nor undernourished.

Orthopaedic treatment—Manipulative reduction and operative fixation were undertaken in a little over half of these cases. In more than one it was found that disimpaction and manipulative reduction were difficult or impossible at the time of operation, thus confirming my own experience that these injuries may be more difficult to reduce than the ordinary traumatic subcapital fractures. Particularly troublesome is the severe degree of impaction which occurs so frequently.

Year of accident—Of sixteen convulsive cases recorded and the two reported here in detail, eighteen in all, twelve have occurred since 1952.

PREVIOUSLY RECORDED CASES

I have found records of twenty-eight cases of bilateral femoral neck fracture, and one case of bilateral intertrochanteric fracture, in the literature: in Table II are details of injuries caused by accident, disease of the femoral neck and epilepsy; in Table III are those from therapeutically induced convulsions. Although much of the information is scanty the male predominance is clearly seen. The age range is less wide than in Table I and most patients were relatively young. Here again the time spent in hospital before injury varies from a few weeks to many years and most of the injuries occurred early in a course of treatment. There is further confirmation of the difficulty of reduction, and of the considerable early mortality.

SIMULTANEOUS BILATERAL CENTRAL DISLOCATIONS OF THE HIP

I have collected details of five simultaneous bilateral dislocations which have occurred in the British Commonwealth since 1950. These details are summarised in Table I. In addition, details of six such cases which have been reported before are shown in Table III. The details of the reported cases are so scanty that few, if any, conclusions can be drawn from them.

SIMULTANEOUS CENTRAL DISLOCATION OF ONE HIP WITH FRACTURE OF THE CONTRALATERAL FEMORAL NECK

Details are given of one case of this very rare double injury (Mr C. M. Squire's patient). These are shown in Table I (Case 26), and the injuries are illustrated in Figures 8 and 9.

FIG. 8

Case 26—Right femoral neck fracture and simultaneous left central hip dislocation occurred in a man of forty-one who was having unmodified electroconvulsive therapy.

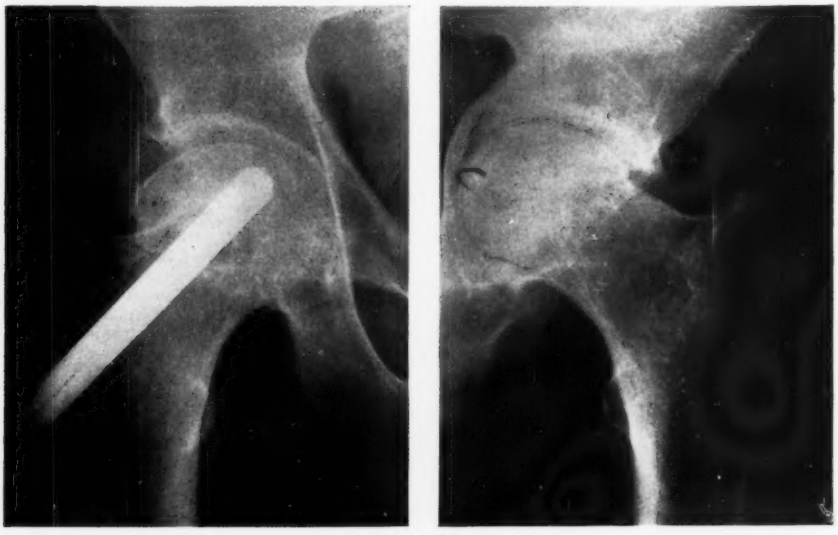

FIG. 9

Case 26—The fracture was treated by nailing, the central dislocation by skeletal traction.

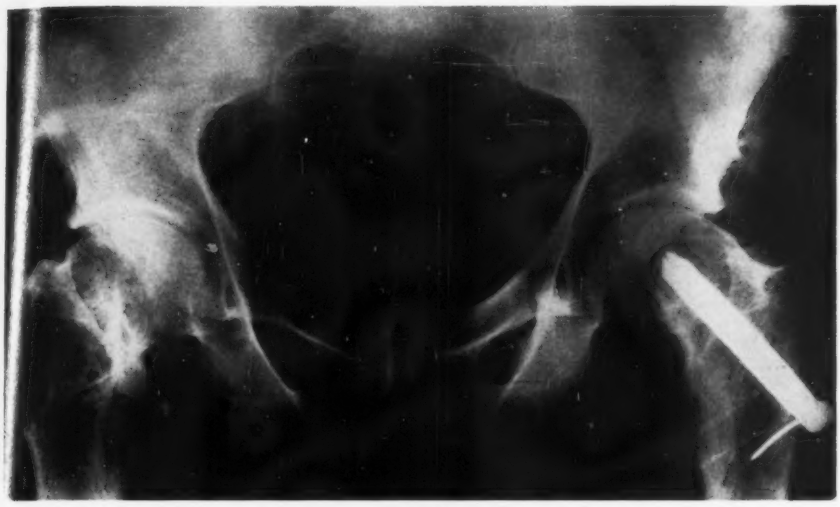

FIG. 10

Case 16—This man had previously sustained bilateral femoral neck fractures while having electroconvulsive therapy. This radiograph shows the state of the hip joints nine years after nailing of the left fracture, osteotomy on the right side being carried out one month after the nailing.

DISCUSSION

Simultaneous bilateral injuries are rare, and the figures of a collected series such as this must be set against the large number of patients treated by convulsive therapy. For the sake of completeness patients have been included whose injuries were not produced by convulsions, but in the large majority convulsive therapy was responsible.

Incidence—These accidents occurred in only a small fraction of the total number of patients given convulsive therapy, either by chemical injection or, more recently, by electrical methods. Several psychiatrists have told me that they have not seen fractures of the femur during twenty years' experience of convulsive therapy. There is a wide variation in the incidence of femoral fractures in previously published reports. Dedichen (1946) reported nine femoral fractures in 2,428 patients in Norway (one of whom had bilateral injuries); Fang (1958) mentioned two bilateral fractures in 1,100 unmodified electrical treatments during 1957 in Hong Kong; Pereira da Silva and Ferreira de Barros (1944) listed three bilateral fractures in 1,843 metrazol and electrical treatments in a period of fifty-five months in Brazil, and Kelly (1954) found one bilateral fracture in 2,200 patients given 37,000 electrical treatments at Lancaster. Smith, Hughes, Hastings and Alpers (1942) thought that the risk of fracture was less with electroconvulsive therapy than with cardiazol-induced convulsions, an opinion shared by Dedichen. Cook (1944) stated that the fractures are much less common with modified treatment. Kalinowsky and Hoch (1952) considered this the most serious injury occurring in convulsion therapy, a statement with which Cummins (1940) agreed. Kalinowsky and Hoch also stressed the difference between the fractures in muscular, younger individuals, and in the elderly.

Mechanism—There are so many mechanical factors to be considered in these double injuries that it is impossible to say with certainty how the fractures occur. Andreini (1956) believed that there is a simultaneous contraction of the pelvi-trochanteric muscles, because only these muscles can apply their force irrespective of the relative positions of the femora and the pelvis. He suggested that when the legs are adducted central dislocations occur, and that femoral neck fractures occur when the legs are abducted. Meschan, Scruggs and Calhoun

FIG. 11

Case 30—These bilateral femoral neck fractures occurred in a man of forty-one, while under treatment for active pulmonary tuberculosis. There was no history of injury, coma or convulsions. His fractures were treated by skeletal traction.

FIG. 12

Case 30—This radiograph shows the state of the hip joints of the man whose injuries were shown in Figure 11. It was taken one year later.

(1950) reported the only case that I have found of bilateral intertrochanteric fractures occurring from convulsive therapy. Fanelli and Modena (1951) suggested the same positional factor in the causation of neck and acetabular injuries. Satta (1938) stressed the influence of well developed muscles; thus the injuries are more likely to occur in men than in women. Baker (1957) held a similar opinion. Santagati (1947) emphasised the danger of fracture in osteoporosis, as did Gissane, Blair and Rank (1940). Most authors have suggested that the tonic phase of the contraction is the stage at which these injuries occur.

Modification of treatment—All the injuries reported here occurred in patients given convulsive therapy without any modification by anaesthesia or relaxants. Baker (1957) stated: "it is known that no fractures occur if muscular relaxants are used, but it is our experience that the death rate is increased by this procedure." Paterson and King (1957) stated that "the only safe way to prevent fractures and other complications is by employing an anaesthetist to give thiopentone and a quick-acting relaxant." At the Maudsley Hospital there has been no fracture since relaxants have been used routinely during the last nine years (Pond 1957). If an orthopaedic surgeon may offer advice to those who specialise in this work, I would emphasise that to the best of my knowledge all these injuries occurred when the treatment was "unmodified."

SUMMARY AND CONCLUSIONS

Cases are reported of two men who sustained bilateral hip injuries while undergoing convulsive therapy and of one woman who sustained bilateral hip injuries during a uraemic convulsion. A further twenty-three previously unreported cases are analysed, sixteen of which were of simultaneous bilateral femoral neck fractures and five of which were simultaneous bilateral central dislocations of the hip. One other patient sustained his injuries in an epileptic fit. A review of the literature has revealed another thirty-five cases of bilateral hip injuries, most of them caused by convulsive therapy, but a few by accident, disease of the femoral neck, or epilepsy.

One case is included of a rare double injury, a femoral neck fracture on one side and a central dislocation on the other. I have found no previous reference to this combined injury.

Double hip injuries are very rare in relation to the large numbers of patients receiving convulsion therapy, but the change from pharmacological to electrical methods has not prevented their occurrence and at least fifteen are known to have occurred during the last six years.

A wide age range is represented, and many fractures of convulsive origin have occurred in fit, well nourished, adult men. Only a few have been found in more elderly and possibly osteoporotic patients.

All the "convulsive" injuries were sustained during unmodified treatment, and mention is made of the differences of opinion among psychiatrists about the use of anaesthesia and of relaxant drugs in convulsion therapy.

These are the most severe injuries complicating convulsion therapy, and the most difficult for the orthopaedic surgeon to treat.

My thanks are due to Mr W. Sayle-Creer for permission to publish details of two patients under his care, to Dr C. S. D. Don for details of his patient, and to other orthopaedic surgeons and to the medical superintendents of the various mental hospitals, who have helped me in my inquiries.

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CONGENITAL DISLOCATION OF THE HIP

A Review and Assessment of Results of Treatment with Special Reference to Frame Reduction as Compared with Manipulative Reduction

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With the object of assessing the results of various methods of treatment of congenital dislocation of the hip used in this centre from 1920 to 1950, a clinical and radiographic review of all available cases was undertaken, the data being grouped according to the initial method of reduction. The results of treatment in this analysis have been assessed according to two criteria: 1) quality of the reduction; and 2) incidence of pathological changes in the head after reduction.

A method of traction and gradual abduction for the reduction of congenital dislocation of the hip was first used in this hospital in 1935 with the purpose of minimising the danger of damage to the blood supply of the femoral head during reposition. Details of this technique were published by Scott (1953). Traction was the method first used for the reduction of a congenital dislocation of the hip, when Pravaz (1837) attempted to bring the femoral head down gradually by prolonged traction and then to manoeuvre it into the acetabulum by a combination of extension, abduction and pressure on the trochanter. Later Putti (1929) introduced his *divaricator* based on similar principles and Keith (1935) developed his traction frame improving on a board devised by McDonald. Forcible reduction by manipulation as described by Paci (1887) and by Lorenz (1895), who widely popularised it, and its modification by Denucé (1898) was the usual method of reduction in most hospitals, including ours, until the method of gradual reduction was developed. During the last few years a new surgical approach to the treatment of congenital dislocation of the hip was introduced in this hospital (Somerville 1953); the present review does not include these later cases.

MATERIAL

All patients with congenital dislocation of the hip in whom reduction was attempted at this hospital from 1920 to 1950 were reviewed. This allowed at least six years to elapse from the completion of treatment to the time that this analysis was begun.

Reduction of one or both hips was performed in 219 patients during that period. We were able to examine 179. The sex ratio was nine girls to two boys. The dislocation was unilateral in 127 patients and bilateral in fifty-two, so that 231 hips were available for analysis. Figure 1 shows the ages at which treatment was begun; although reduction was attempted up to the age of nine, only three patients were over the age of six at the time of starting treatment. Patients with bilateral dislocations came for treatment later than those with unilateral affection, probably because walking started later in the bilateral cases (Fig. 1).

ASSESSMENT OF RESULTS

Quality of reduction—It is probable that the wide variations in the results of treatment published by different authors have been due more to differences in methods of analysis than to real differences in clinical results. In the present investigation the results obtained with various methods of treatment were uniformly assessed.

Estimation of the functional result many years after treatment has ended is a good way of assessing the merits of any treatment. However, for two main reasons we have not used this method in our study of cases of congenital dislocation of the hip. Firstly, many years

must elapse before one can with certainty assess the final result; a sufficiently long period of follow-up could not have been obtained in the more recent cases included in this study. Secondly, pain, the main symptom of abnormal function, is difficult to assess. A dysplastic joint may not give rise to symptoms and may function normally for a considerable number of

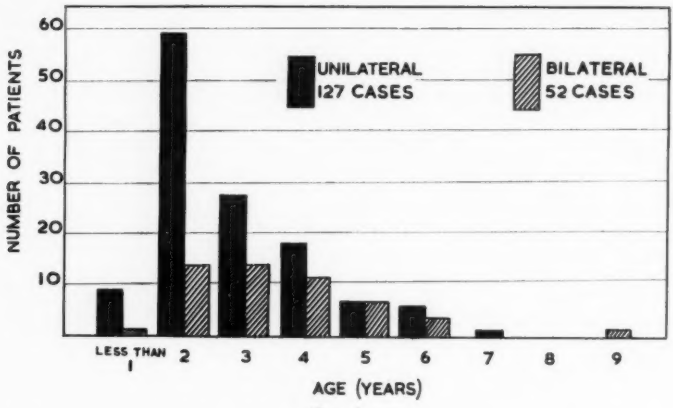
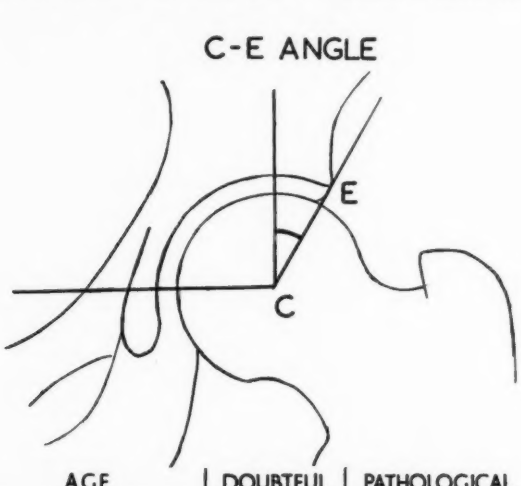


FIG. 1

Age at which treatment was started in the 179 patients available for review.



AGE	DOUBTFUL	PATHOLOGICAL
6 TO 13 YEARS	15°–19°	UNDER 15°
14 YEARS AND OVER	20°–25°	UNDER 20°

FIG. 2

The CE angle (Wiberg 1939). The angle between two lines passing through the centre of the head (C), one perpendicular to the line joining the centres of the heads, the other tangential to the edge of the acetabulum (E).

years and yet later deterioration may be almost inevitable. Putti (1933) expressed this concept in the following words: " No complete and permanent restoration of function occurs without a perfect anatomical reduction." For this reason early estimates of functional results of any method of treatment of congenital dislocation of the hip are misleading. An anatomical

classification of results, based on the shape of the femoral head and the relationship between it and the acetabulum, allows an objective assessment of the quality of reduction and of the subsequent development of the joint, and permits a forecast of the final result.

Method of assessment of quality of reduction—The hips have been classified according to the relationship between the head and the acetabulum as seen in the radiographs. The classification also takes into consideration the anatomical configuration of the femoral head and neck, which is often affected by pressure after reduction. These changes are studied in the next section.

For this anatomical assessment we have used Severin's (1941) six categories based on the anatomical configuration of the femoral head and neck and of the acetabulum, and their relationship to one another. The relationship between the head and the acetabulum has been expressed as the CE angle (Wiberg 1939). This angle is formed by two lines passing through the centre of the femoral head, one of which is perpendicular to the line uniting the centre of the two heads and the other tangential to the edge of the acetabulum (Fig. 2).

Type I—The hip is perfect in all respects, with rounded head and normal neck and acetabulum: *a*) the CE angle is more than 19 degrees between the ages of six and thirteen, and more than 25 degrees for ages from fourteen upwards (Fig. 3); *b*) the CE angle is from 15 to 19 degrees between the ages of six and thirteen, and from 20 to 25 degrees for ages from fourteen upwards (Fig. 4).

Type II—The head and/or neck of the femur reveals moderate deformity, the shape of the acetabulum is good and there is no subluxation: *a*) the CE angle is the same as in Type I*a* (Fig. 5); *b*) the CE angle is the same as in Type I*b* (Fig. 6).

Type III—There is dysplasia of the acetabulum but no subluxation of the joint. The CE angle is less than 15 degrees in ages from six to thirteen years, and less than 20 degrees in ages from fourteen upwards (Fig. 7).

Type IV—The femoral head is subluxated and articulates with a shallow acetabulum: *a*) positive CE angle, or equal to zero (Fig. 8); *b*) the CE angle is negative because the subluxation is greater (Fig. 9).

Type V—The femoral head articulates with a "secondary" acetabulum developed in the higher part or on the edge of the true acetabulum. In this type, as in Type IV, there is often considerable deformity of the head and neck of the femur (Fig. 10).

Type VI—There is a complete dislocation (Fig. 11).

ANATOMICAL RESULTS

Manipulative treatment—In eighty hips in fifty-seven patients reduction was attempted by manipulation. Of these, twenty-six hips (32·5 per cent) needed open reduction later and are considered in a special section. Five hips (6·3 per cent) had a shelf operation. One hip had a rotation osteotomy. Seven patients in this group did not attend the follow-up. Table I shows the anatomical results related to the age at initial reduction. A total of 26·8 per cent of the hips showed a perfect or good reduction, 32 per cent had a moderate result and 21 per cent showed failure of reduction.

Frame reduction—One hundred and twelve hips in ninety-two patients were treated by gradual reduction on a frame. Of these, fifteen hips (13·3 per cent) required open reduction later and are considered below. Ten hips (8 per cent) had a shelf operation. Twelve had a rotation osteotomy and one a combined acetabuloplasty and rotation osteotomy.

We have been able to assess the results in eighty-one hips. The anatomical results of these related to the age at initial reduction are shown in Table II. A total of nearly 60 per cent belong to groups I, II and III of Severin which we consider as perfect and good results. The slight or moderate residual subluxations accounted for 32 per cent and total failures 8 per cent. Analysis by age shows that the best results were obtained when treatment began before the age of two and a half years, and results were less satisfactory when the patient started treatment later.

FIG. 3

FIG. 4

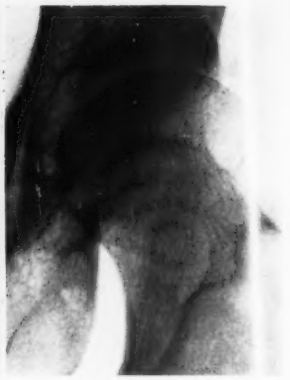


FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

FIG. 10

FIG. 11

Classification of results on anatomical basis. Figure 3—Type I*a*. Figure 4—Type I*b*. Figure 5—Type II*a*. Figure 6—Type II*b*. Figure 7—Type III. Figure 8—Type IV*a*. Figure 9—Type IV*b*. Figure 10—Type V. Figure 11—Type VI.

Open reduction—Open reduction was carried out in fifty-five hips; in twenty-six of these previous manipulation had failed; in fifteen attempted reduction on a frame had failed; in twelve open reduction was used as a primary treatment; and in two previous attempts at reduction by operation had failed.

TABLE I

ANATOMICAL RESULTS OF HIPS TREATED BY MANIPULATION RELATED TO THE AGE AT INITIAL REDUCTION

Age up to	Number (hips)	Perfect			Good				Poor			Total failures		
		I*a*	I*b*	Per cent	II*a*	II*b*	III	Per cent	IV*a*	IV*b*	Per cent	V	VI	Per cent
2 years	10	2	—	20	3	1	—	40	3	—	30	1	—	10
2½ years	12	2	2	33	—	4	2	50	1	1	17	—	—	—
3 years	3	—	—	—	—	—	1	33	1	—	33	1	—	33
4 years	11	1	—	9	2	—	2	36	1	3	36	1	1	18
5 years	10	—	—	—	—	—	—	—	4	1	50	3	2	50
9 years	1	—	—	—	—	—	—	—	—	—	—	1	—	100
Total .	47	5	2	14·9	5	5	5	31·9	10	5	32	7	3	21
		22 hips: 46·8 per cent							15 hips: 32 per cent			10 hips: 21 per cent		

TABLE II

ANATOMICAL RESULTS OF HIPS REDUCED ON FRAME RELATED TO THE AGE AT INITIAL REDUCTION

Age up to	Number (hips)	Perfect			Good				Poor			Total failures		
		I*a*	I*b*	Per cent	II*a*	II*b*	III	Per cent	IV*a*	IV*b*	Per cent	V	VI	Per cent
1 year	3	1	—	33	1	—	1	67	—	—	—	—	—	—
2 years	20	7	2	45	1	2	3	30	3	2	25	—	—	—
2½ years	22	5	1	27	2	1	9	55	4	—	18	—	—	—
3 years	10	1	—	10	1	2	3	60	2	—	20	—	1	10
4 years	6	—	1	17	2	—	—	33	2	—	33	1	—	17
5 years	13	—	—	—	—	—	1	8	8	1	68	—	3	23
6 years	5	—	—	—	—	—	1	20	3	—	69	1	—	20
7 years	2	—	—	—	—	—	—	—	—	1	50	1	—	50
Total .	81	14	4	22·2	7	5	18	37·0	22	4	32	3	4	8
		48 hips: 59·3 per cent							26 hips: 32 per cent			7 hips: 8 per cent		

The results of open reduction could be assessed in forty-four hips. The relationship between the anatomical results of open reduction and previous treatment is shown in Table III.

The cases have been divided into two groups, one comprising patients operated on prima ily or immediately after the failure of a previous reduction, and the other including patient who continued to have conservative treatment with plasters in spite of an unsatisfactory redu tion. These were operated upon after a variable period of plaster immobilisation. At the time of operation they were on average nine months older than the patients of the first g oup. It will be seen that the results were more satisfactory when open reduction followed immed tely the failure of the closed method of reduction, whereas open reduction rarely succeeded /hen the patient had been kept in plaster with the dislocation unreduced. Of eighteen such ases only one had a good anatomical result, while all the others had either some degree of res idual subluxation or complete failure of reduction.

TABLE III

RELATIONSHIP BETWEEN THE ANATOMICAL RESULTS OF OPEN REDUCTION AND PREVIOUS TREATME T

Open reduction performed	Number (hips)	Perfect			Good				Poor			Total failures		
		I*a*	I*b*	Per cent	II*a*	II*b*	III	Per cent	IV*a*	IV*b*	Per cent	V	VI	Per cent
Primarily, or immediately after manipulation or traction in frame	26	6	1	27	4	1	1	23	5	1	23	4	3	27
After two to thirteen months in plaster, or weight bearing, after the initial treatment	18	—	—	—	—	1	—	5	6	2	44	5	4	50
Total . . .	44	6	1	16	4	2	1	16	11	3	32	9	7	36

INCIDENCE OF OSTEOCHONDRITIS OF THE FEMORAL HEAD AFTER REDUCTION

During the early phases of treatment osteochondritis may occur in the femoral head with consequent changes in the anatomical and late functional results. Schede (1940) did not believe that the trauma of reduction was responsible for these changes and considered that the fragmentation observed was a sign of ossification; but others believe that the radiological changes are signs of femoral dysplasia (Gill 1948). The figures for the incidence of changes in the femoral head after similar methods of reduction vary from author to author; thus Crego and Schwartzmann (1948) claimed 0 per cent, Ortolani (1948) 2 per cent, Farrell and Howorth (1935) 10·2 per cent, Massie (1951) 45 per cent after closed reduction and 30 per cent after open reduction, Ponseti (1944) 46·2 per cent, Judet (1958) 51 per cent after closed reduction and 22 per cent after open reduction, and Bost, Hagey, Schottstaedt and Larsen (1948) 52 per cent. This wide disparity may be related not so much to the different methods of treatment used but to a variation in the interpretation of the findings and to the different methods of analysis employed. In fact, in some papers this discrepancy is not even considered and in others it is regarded as inevitable. Some authors have included in their figures only those cases presenting advanced changes resembling coxa plana; others include all changes occurring in the head after reduction, while some give no definition of the lesions. Massie (1951) found that, apart from the 30–45 per cent of hips which showed coxa plana, 40 per cent had some abnormal epiphysial changes without fragmentation, a lesion which he considered indicative of a vascular disturbance of the head. Therefore, 75 per cent (forty-seven out of sixty-two hips) showed some radiographic abnormality, and 72 per cent of those whose lesions were attributed to vascular disturbances had trouble with their hips in later life.

To summarise, it may be said that when cases have been studied in detail, as in the series of Ponseti and of Massie, it has been shown that a high proportion of patients show radiographic changes in the head which appear to have great significance for the condition of the joint in later life.

Classification—Changes in the radiographic appearance of the femoral head after reduction have been studied and the consequent permanent deformities classified in four groups,

FIG. 12

FIG. 13

FIG. 14

FIG. 15

Classification of severity of osteochondritis. Figure 12—Type I. Figure 13—Type II. Figure 14—Type III. Figure 15—Type IV.

according to severity. *Type I*—Head and neck of normal appearance (Fig. 12). *Type II*—Some flattening of the head; neck moderately wider and shorter than normal (Fig. 13). *Type III*—Mushroom-shaped head spreading over a shorter and generally wider neck (Fig. 14). *Type IV*—The femoral head and neck grossly misshapen, the head nearly touching the trochanter, because of extreme shortening of the neck (Fig. 15).

Incidence related to method of reduction—Of the total number of hips initially treated by manipulation or by the frame method, we have analysed only those in which there is a series of radiographs covering the whole process of reduction and after-treatment. We have not considered the cases of primary operative reduction because of their small number. One hundred and forty-one hips were available: seventy-seven reduced by frame and sixty-four by

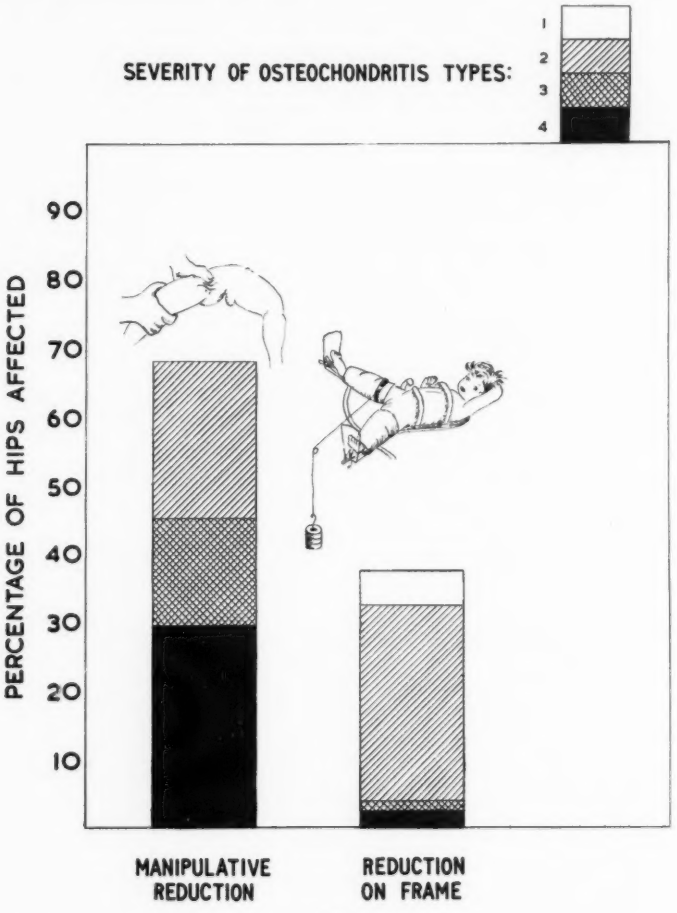


FIG. 16

Incidence and severity of osteochondritis. Two groups compared: primary treatment by manipulative reduction; primary treatment by reduction on frame. Showing the increased incidence and severity of osteochondritis after manipulative reduction.

manipulation. The final anatomical results of those hips which had exhibited early radiological changes after reduction have been assessed and classified.

It may be seen from Table IV and Figure 16 that the frame treatment gave an incidence of osteochondritis of 37·7 per cent, from very slight to severe, against 68·6 per cent in cases reduced by manipulation. The severity of the disturbance in the cases treated by frame was much less, only 2·6 per cent of the cases producing final gross deformity, as compared with 29·7 per cent of severe deformities in the cases of manipulation.

The frame treatment proved to be of value in lessening the incidence of severe lesions in the head and neck, for there were only two cases in which this complication developed.

An observation in relation to the pathogenesis of these lesions is worth reporting: a boy aged ten months with subluxation of the left hip (not included in this analysis) was treated primarily in plaster in the position of full bilateral medial rotation and abduction without previous attempt at reduction. He showed five months later osteochondritic changes in both femoral heads. These changes started on the normal side and were followed afterwards by similar changes in the previously subluxated hip (Figs. 17 to 19). It is believed that the position of the leg in plaster had some bearing on the production of the lesion; the persistent overstretching of the capsule when the leg was forcibly abducted with the adductors intact

TABLE IV

INCIDENCE AND SEVERITY OF PATHOLOGICAL CHANGES IN THE FEMORAL HEAD RELATED TO THE METHOD OF INITIAL REDUCTION

Method of reduction	Hips	Per cent	Final anatomical results							
			Normal		Slight deformity		Severe deformity		Very severe deformity	
			1		2		3		4	
			Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Manipulation	64	68·6	—	—	15	23·3	10	15·6	19	29·7
Frame . .	77	37·7	4	5·2	22	28·4	1	1·4	2	2·6

(Nicholson, Kopell and Mattei 1954) may have been responsible for the lesion. Another possible cause is reflex vascular spasm of the capital vessels of the normal side. This has been shown by Barnes and Trueta (1942) to occur experimentally in the femoral and iliac arteries of the rabbit when the opposite leg is constricted by a tourniquet.

DISCUSSION

Gradual frame reduction of congenital dislocation of the hip has proved to have several substantial advantages over manipulative treatment, the most important of which is a diminished incidence and severity of osteochondritis; consequently a greater number of hips had a perfect final anatomical result. It has also proved to be a more effective method of reduction, failing less often than manipulative methods.

Dislocations in older patients, in whom radiography showed a long distance from the top of the ossific nucleus of the head to the Y-line, proved to be difficult if not totally impossible to reduce without operative removal of the obstacle to reduction.

It seems clear that efforts should be made to improve the quality of primary reduction. Arthrography—used in the later cases of this series—is likely to be helpful in assessing the quality of reduction and in indicating those cases in which open reduction should be used.

SUMMARY AND CONCLUSIONS

1. The "frame" or traction method of reduction of congenital dislocation of the hip is, from the evidence collected in this hospital, both more effective and safer than the manipulative method of reduction. The traction method caused less frequent and less severe lesions of the femoral head than the manipulative method.

2. In cases in which closed reduction failed, open reduction was attempted; the quality of the results depended mainly on the time of operation, the best being in patients operated upon a few weeks after the initiation of the frame treatment.

FIG. 17

Congenital subluxation of left hip after ten months' immobilisation in plaster which kept both hips in a position of full medial rotation and abduction. Osteochondritic changes present in both hips.

FIG. 18

The same patient fourteen months later. Progression of the osteochondritic changes. The changes are more advanced in the hip which was subluxated.

FIG. 19

Two years later. The right hip shows restoration to an almost normal state, while the left (subluxated) hip does not yet show full healing.

3. Even with its improved results, still about 40 per cent of cases treated by the frame method showed insufficient reduction or structural changes of the femoral head.

4. Arthrography may help in indicating those cases in which open reduction is desirable.

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NORMAL AND ABNORMAL GROWTH AT THE UPPER END OF THE FEMUR

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It is the purpose of this paper to describe and illustrate how alterations in the fe ility and position of the primary and secondary epiphyses may affect the shape and length c the upper end of the femur.

It is suggested that under normal conditions of growth two processes are invo ed: firstly, ossification of parts of the cartilaginous anlage; and secondly, growth of the who e.

Ossification takes place in each area in which a blood supply is present: namely, 1) *i the shaft*—periosteal arteries and nutrient artery; 2) *in the metaphysis*—nutrient arteries; and 3) *in the epiphysis*—epiphysial arteries. The shaft with its double blood supply is oss fied long before the epiphysis.

Growth of the whole—Growth in length takes place at both ends of the bone in the area kn own as the epiphysial plate. Growth in width follows the increase in diameter of the epiphysi .

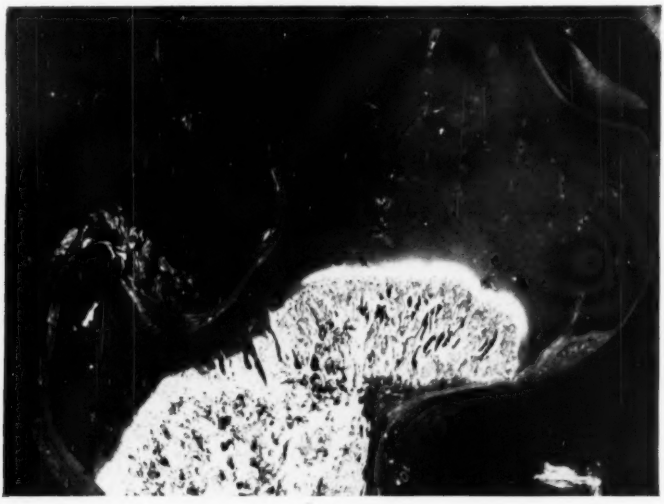

FIG. 1

Section of upper end of foetal femur showing crescentic shape of pre-plate.

DEVELOPMENT OF THE FEMUR

At birth the shaft is a calcified tube containing the actively proliferating nutrient vessels and closed at its ends by the cartilaginous epiphyses. Each epiphysis has one or more vascular islands—the ossific nucleus—but the epiphysial " plate " is not yet fully formed.

As age advances the mature epiphysial plates are formed—each in its own time and place.

A mature plate consists of a circumscribed area in which the cartilage cells are arranged in columns, the whole being sandwiched between the bony end plates of epiphysis and metaphysis. In this situation the cells are subjected to the growth pressure and by the r

interposition they separate the vascular territories of the metaphysis and epiphysis. Multiplication of these cartilage cells leads to growth in length of the bone and this growth takes place in the direction of the columns. At the lower end of the femur this direction is roughly in the line of the shaft of the bone.

Growth from the lower plate commences at an early age by pushing before it the almost flat side of the B-shaped lower epiphysis, adding length to the end of the bone as from an indented disc.

At the upper end of the femur the epiphysial plate is more complex. At first it appears to stretch across the upper end of the bone as a crescentic line (Fig. 1), but this effect is soon modified by the appearance of a mature portion of the plate on the medial side opposite to the newly formed and vascular capital epiphysis. Vigorous growth by this mature part of the crescent leads to an elongation of the femoral neck. Because of this early and unopposed spurt of growth the femoral neck at this age is more vertical than in the adult, a normal condition known as infantile coxa valga.

Such a state of affairs does not last long, probably because of the wakening activity of the hip abductors in walking, for the lateral portion of the crescentic pre-plate now becomes organised, after the appearance of a new vascular " island " in contact with it. This is the epiphysis of the greater trochanter.

Thus there are two separate areas at the upper end of the bone where rapid growth is taking place. Increase in length is therefore, as it were, a resultant of these two forces interacting to determine the angle of the neck and the length of the shaft.

The first effect of the increasing growth activity of the lateral part of the plate is a marked lessening of the valgus angle of the neck. This is accomplished by increasing growth of the lateral part of the shaft. It can readily be imagined, therefore, that anything which interferes with this sequence of events will lead to deformity of the upper end of the bone and almost always to some permanent shortening of the thigh.

It is said that only 30 per cent of the length of the femur is produced by the upper epiphysial plate. But, as most of this growth takes place in the first few years of life, any interference with it then will cause the greatest deformity. It is interesting to review the progress of such abnormalities of the upper end of the femur as congenital coxa vara in the light of this concept of its longitudinal growth. Following the progress of such a case by serial radiographs may provide ideas regarding its etiology and may suggest some effective mode of treatment.

PATHOLOGICAL CONSIDERATIONS

Congenital coxa vara—Figure 2 shows such a case. The radiograph was taken on the day of birth. Eight months later the radiograph (Fig. 3) showed that the ossific nucleus of the femoral head was just visible, placed centrally in an acetabulum which was quite well developed. It also showed a dark shadow appearing as the " ghost " of the missing upper end of the femur. The relationship of the " ghost " to the ossified shaft suggested fracture of the shaft of the femur. In fact the mother did volunteer the information that in the eighth month of pregnancy she fell heavily on to her abdomen when going upstairs.

The appearance of the radiograph (Fig. 3) suggested that the upper end of the femur was present but still cartilaginous. This was later confirmed by arthrography (Fig. 4) which showed a normal head, neck and acetabulum, and by the finding at subsequent exploration of trochanters and of the upper end of the femoral shaft. If a fracture had in fact occurred at the time of the accident, when the femoral shaft would be as much cartilage as bone, it would have taken place either through the cartilaginous shaft or at the place where cartilage and bone joined. Whichever was the case the rhythm of ossification previously described—which we believe to be essential for normal growth in length—would have been interrupted. The failure of the spread of ossification from below would have prevented the development of a normal epiphysial plate, so that if the upper end of the femur were eventually to undergo

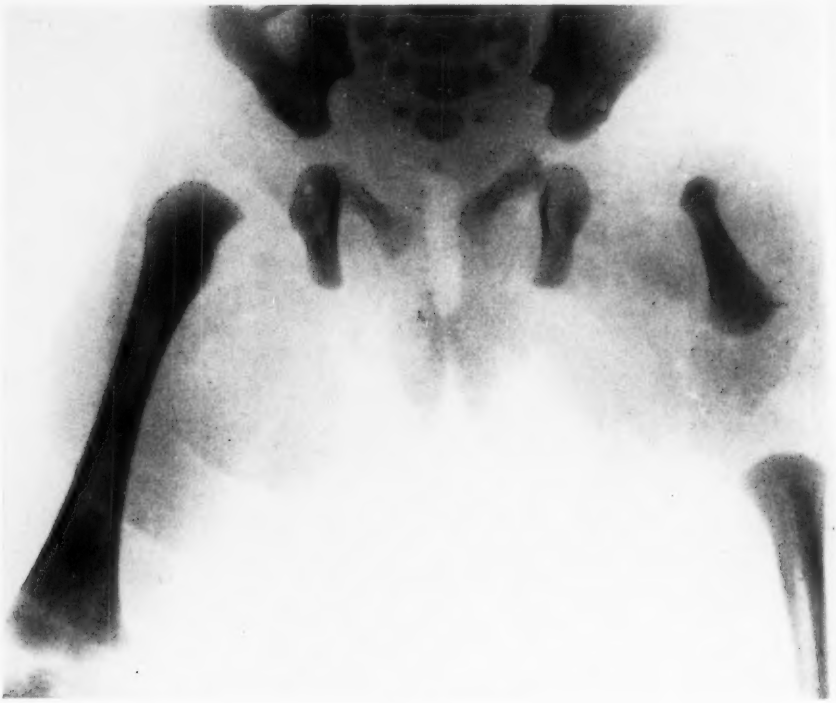

FIG. 2
Radiograph of child on the day of birth, showing typical congenital coxa vara.

FIG. 3 FIG. 4

Figure 3—Same child eight months later. The ossific nucleus of the femoral head is now visible in the acetabulum and the upper end of the femur is appearing as a " ghost." Its relationship to the shaft is similar to that in cases of birth fracture. Figure 4—An arthrograph of this hip outlines the cartilaginous head and neck.

FIG. 5

FIG. 6

Figure 5—At a later stage the capital nucleus is extending into the neck and irregular nuclei are developing.
Figure 6—The irregular nuclei are fusing together.

FIG. 7

FIG. 8

Figure 7—A similar case at a later stage. Figure 8—The same case after the varus deformity was corrected by osteotomy. The whole of the upper end of the femur has fused into one solid mass, without the property of growth in length.

ossification it could only do so in an irregular manner. Serial radiographs showed that patchy ossification occurred in the cartilaginous part which eventually fused into a solid mass which, in its turn, fused with the ossific nuclei in the head and trochanter (Figs. 5 and 6). Thus, the

FIG. 9

Congenital coxa vara. In these hips the defect is in the femoral neck. The trochanteric part of the epiphysial plate is intact so that growth in length can continue here normally. Note the triangular piece of bone.

FIG. 10

Same case as Figure 9. The femoral head has got left behind. The " defect " has closed spontaneously.

upper end of the femur became one solid mass of bone without a metaphysis, and without hope of longitudinal growth. This solid upper end of the femur will eventually join the shaft spontaneously; in this case it was assisted by an osteotomy (Figs. 7 and 8).

The lesion causing the interruption in ossification just described was below the trochanter but it may be in the neck. In that case the ossification of the shaft will spread upwards forming a normal epiphysis with the greater trochanter. It cannot, however, extend into the neck, so that no metaphysis will develop for the head, no growth will take place, and the head will get left behind. In this instance a gross and increasing coxa vara results (Figs. 9 and 10).

There are certain instructive features about this lesion. Trueta (1957) has demonstrated the blood supply of the upper end of the femur by the injection method. The growing head of the femur derives its blood supply from two sources: the more lateral part of the head

FIG. 11

Operative findings in case shown in Figures 2 to 6. The fibrous union between the bony shaft and the cartilaginous upper end can be seen.

from a leash of vessels on the upper surface of the neck; and the medial part by a smaller leash on the under surface. This lower part of the head is mainly proximal to the epiphysial line but a small portion lies distal to it. Thus the ossific nucleus of the head, with a small triangular portion of the neck adjacent to the medial part of the head, will have a blood supply of its own which is unaffected by the lesion in the neck. The whole segment may ossify quite normally, giving the appearance of a normal femoral epiphysis and a triangular piece of bone (Fig. 9).

These observations on the etiology of this condition suggest certain points which may be of value in treatment. There are the two types of coxa vara. In the first the lesion is distal to the trochanter, and in the second it is proximal to it. There are two problems: firstly, the deformity. This is static in the first type throughout the period of growth and is progressive in the second type. Secondly, the failure of normal growth in length: in the first type this will be extreme, there being no upper metaphysis or plate at all, but in the second it will be minimal because the trochanteric metaphysis and portion of plate will continue to grow uninterruptedly.

Whereas the deformity presents no problem (it can be corrected easily by osteotomy) the problem of growth may be insuperable. Nevertheless, there are certain possibilities worth considering even with this.

If ossification could be made to spread across the defect from the ossified shaft into the cartilaginous part, so that it might continue upwards in an orderly manner before the

disorganised ossification had begun, it might be possible for an epiphysial plate to form and for growth in length to be restored. With this possibility in mind we explored the upper end of the femur in the case illustrated in Figure 2. We found the cartilaginous upper end of the femur joined to the ossified shaft by a fibrous union at which movement could take place (Fig. 11). An osteotomy was carried out close to the end of the bone, a drill was passed across the fibrous union from the bone into the cartilaginous mass and the deformity was corrected at the osteotomy. The procedure was unsuccessful.

The cause of failure may have been the great difficulty of maintaining apposition at the osteotomy in such a short, fat leg; it may have been that at ten months of age we were already too late; or it may have been that we were attempting the impossible. But in spite of this failure we feel that further attempts should be made to get bone to fuse to cartilage in order that normal ossification may progress from the bone into the cartilage.

We do not wish to convey the impression that we believe that congenital coxa vara is always the result of trauma such as recorded here, but rather to suggest that any lesion that will in some way prevent the upward spread of ossification will cause this condition. The spread of ossification is dependent entirely on blood supply. If the blood supply is interrupted the spread will cease. Trauma is only one way by which the blood supply may be stopped.

Other conditions affecting the upper end of the femur—Less spectacular changes in the upper femoral epiphysis may follow paralysis of the abductors, as commonly occurs after anterior poliomyelitis, the loss of tension in the trochanteric epiphysis tending to close the lateral portion of the plate so that the medial or subcapital part of the plate overgrows with resultant coxa valga (Fig. 12).

In most patients with Perthes' disease deformity occurs with little if any shortening of the thigh. In this condition revascularisation of the ischaemic capital epiphysis leads to the maturity of a larger piece of the crescentic pre-plate than normal, so that the wide incongruous head is supported on a short, thick neck, while at the unaffected trochanteric portion of the plate growth continues steadily and is thus able to maintain the length of the shaft (Fig. 13).

FIG. 12

Some of the most severe and bizarre abnormalities of growth at the upper end of the femur follow acute infections of that region in early life. In such cases the infective process destroys part or whole of the capital anlage or epiphysis and as a result either the plate is never formed or, if present, it is closed. In some cases only the medial (subcapital) part of the plate is destroyed. When this happens no head or neck is formed, but the length of the femoral shaft is maintained undisturbed by the activity of the undamaged lateral (trochanteric) part of the plate (Fig. 14). In other cases the damage to the subcapital epiphysis is incomplete and the viable portions of the plate grow a long, thin and irregular neck which may even have a head at its summit (Fig. 15). Lastly,

FIG. 12

Radiograph of the femora after poliomyelitis, showing shortening of the right femur and coxa valga.

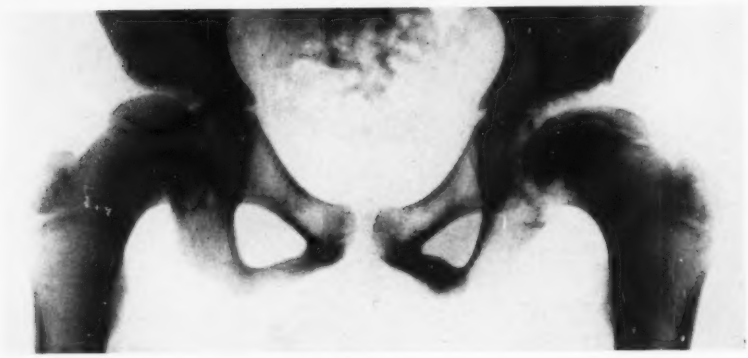

FIG. 13
Perthes' disease of left hip, showing short, thick neck with normal trochanteric epiphysis.

FIG. 14

FIG. 15

Figure 14—Infection has destroyed the femoral head; the neck is absent but the length of the shaft is normal. Figure 15—Infection has injured the whole of the upper epiphysis. Irregular neck and trochanter formed with much shortening.

FIG. 16

FIG. 17

Antero-posterior and lateral radiographs showing distortion of head due to central closure of growth plate.

partial subcapital damage may distort the head, because one part of the plate is closed and another still open (Figs. 16 and 17).

Finally, it might perhaps be true to describe adolescent coxa vara as the swan song of the upper femoral plate because, goaded by hormones, the epiphysis and plate slip away.

SUMMARY

1. A brief description is given of normal epiphysial growth of the human femur.
2. Some ways in which abnormality of the growth plates may affect the shape and length of the human femur are described.
3. The influence of the blood supply on growth is discussed with particular reference to the etiology and treatment of congenital coxa vara.

We would like to thank our colleagues for allowing us access to this material, and Professor J. Trueta for his enthusiastic and unfailing help.

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THE PATHOLOGY OF SLIPPED UPPER FEMORAL EPIPHYSIS

A New Concept*

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The weakest part of the epiphysial plate is the layer of cartilage cells nearest the metaphysis. If the overlying periosteum is incised, a separation through this layer is easily produced (Harris 1917). Even if it is conceded, as shown experimentally by Harris (1950), that, in rats treated by growth hormone, broadening of this layer can diminish the cohesion of epiphysis and metaphysis, the resistance to slipping of the upper femoral epiphysis offered by a strong, intact periosteum is nevertheless great. Its rupture, necessary before slipping can take place, is likely to produce symptoms more acute than are usual in the case with gradual onset.

It is too easily assumed that slipping is the first recognisable change in position of the femoral head.

From a study of lateral radiographs of slipped epiphyses, I have been impressed by the frequency with which the back of the femoral neck is materially shorter than the front (Fig. 1).

FIG. 1

FIG. 2

FIGS. 1 AND 2

Figure 1—The left hip of a girl aged twelve who had symptoms for one year. Figure 2—A lateral radiograph of a similar hip in a girl aged eleven showing the diminished growth of the posterior part of the metaphysis.

The essential nature of this relative shortening can be seen in Figure 2, in the lateral radiograph of the right hip of a girl of eleven who had an intermittent ache in the thigh for six weeks. The line of the metaphysis, instead of describing a regular ellipse, falls away abruptly behind a point at the junction of the anterior quarter with the posterior three-quarters, and gives the impression of diminished growth of this segment.

* This paper was read before the meeting of the British Orthopaedic Association at Torquay in 1959.

An index of this may be obtained by measuring what I shall term " the angle of tilt." This is the posterior angle enclosed by a line passing through the apices of the anterior and posterior corners of the metaphysis, and one drawn at 90 degrees to the rectilinear shadow cast by the lateral part of the front of the femoral neck. This was measured in twenty normal children, aged twelve to sixteen and found to average 10 degrees (Fig. 3). It was also measured in thirty-six hips in patients with slipped epiphysis, comprising twenty-two hips with a gradual onset of symptoms four symptomless contralateral hips, and ten in which, although the onset was definite, symptoms were never severe. The average angle in these thirty-six hips was 30·5 degrees. Cases which presented with sudden displacement without a previous history, and those in which radiographs showed evidence of adaptive changes which would vitiate the measurements, were excluded.

FIG. 3
The angle of tilt in a normal hip is 10 degrees.

ILLUSTRATIVE CASES

Case 1—A girl aged eleven was admitted to a medical ward in July 1950, because of " rheumatism," having complained of aching in the right thigh for two months and in the left for two days. A lateral radiograph of the right hip (Fig. 4) showed a marked defect of bone growth in the posterior two-thirds of the metaphysis, producing an angle of tilt of 35 degrees.

Eleven months later, premature fusion has taken place across the posterior half of the epiphysial plate, which remained open anteriorly. This has resulted in an increase in the angle of tilt to 47 degrees (Fig. 5).

The left hip of the same child showed a disturbance of growth at an earlier stage (Fig. 6).

FIG. 4

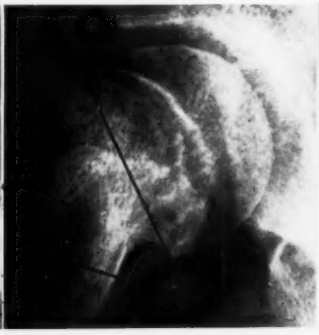

FIG. 5

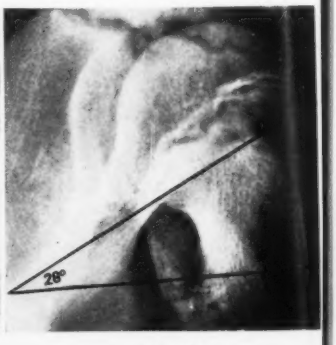

FIG. 6

Case 1. Figure 4—The right hip of a girl of eleven with a two months' history. Figure 5—The angle of tilt shows an increase from 35 degrees to 47 degrees over a period of eleven months. Figure 6—The left hip also shows a disturbance of growth at an earlier stage.

Case 2—A girl of twelve was admitted with a typical slipped epiphysis of the left hip. She had no symptoms in the right hip (Fig. 7) which, however, showed notable shortening of the back of the neck and a tilt of 28 degrees.

When the head of the femur becomes tilted its position is unstable, and it is liable to become grossly displaced as a result of minor injury.

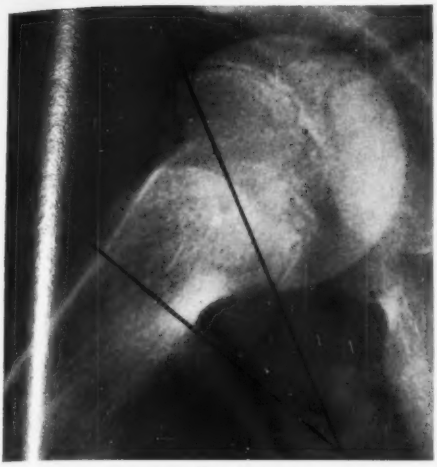

FIG. 7

Case 2—The symptomless right hip in a girl admitted with a slipped epiphysis of the left hip. The right hip has an angle of tilt of 28 degrees.

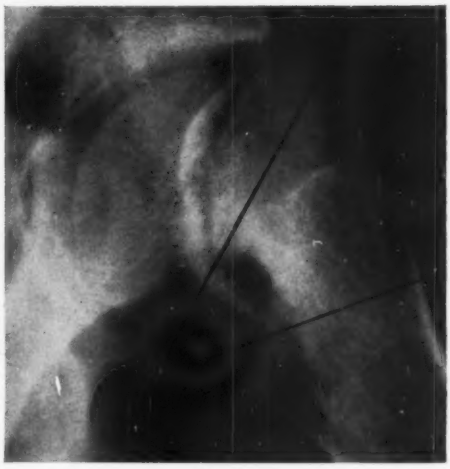

FIG. 8

Case 3—This boy has an angle of tilt of 42 degrees. He had sustained an injury two years previously.

Case 3—A boy of fifteen and a half had complained of pain on the outer side of the left hip and thigh for six months. It was at first present only when he got up in the morning, but had recently become severe. Two years previously he had fallen off a pony, and had been dragged some distance with his left leg entangled in the reins.

A 50 per cent recent slip has been preceded by an angle of tilt of 42 degrees (Fig. 8).

Two objections will immediately be raised. The first is that the angle will depend largely on the position of the patient. Actually I have found that slight alterations in position in taking a lateral radiograph have produced little change in the angle. The validity of this was further tested by taking four lateral views of an anatomical specimen in different degrees of lateral rotation (Fig. 9).

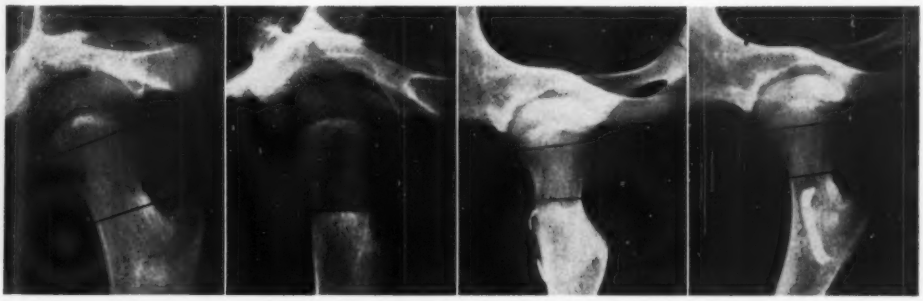

FIG. 9

Four lateral views in different degrees of rotation of an anatomical specimen.

It will also be objected that the relative increase in the length of the front of the neck is not primary, but secondary to callus laid down in the wake of an epiphysis which has already slipped. This does occur, but must surely be preceded by severe disability. It is difficult to believe that this can take place quietly with only minor symptoms. Slight pain, or the presence of a painless limp, is more compatible with a gradual alteration in the axis of the head.

It is my contention that the relative increase in the length of the front of the femoral neck is due to a primary failure of growth of the back of the femoral neck.

Why should the back of the neck fail to grow, while normal anterior growth takes place? The most likely cause is compression of the back of the epiphysial plate. This is in keeping with the known effect of acute compression of an epiphysial plate, of which varus of the ankle is a well known example (Fig. 10). Such compression could be applied acutely by forced lateral rotation in extension. In twelve of these patients there was in fact, a history of a considerable injury at intervals varying from three to twenty-four months before admission to hospital.

FIG. 10
An example of varus of the ankle due to failure of normal epiphysial growth.

Acute compression cannot, however, explain the tilt in the others. According to Frazer (1933), the line of incidence of gravity of the upright trunk passes through the back of the hip, and would tend to bend the trunk backwards were it not for the anterior ilio-femoral ligament. The compression force capable of being exerted on the back of the epiphysial plate must be considerable. I believe, therefore, that it is probable that a static compression force plays a part in the majority, and especially in those patients who are overweight.

I have found evidence of diminished or arrested growth in other joints in patients with slipped upper femoral epiphyses where this concept of compression of an epiphysial plate is applicable.

FIG. 11
Case 4—Left hip showing slipped epiphysis.

ILLUSTRATIVE CASES

Case 4—A girl of fifteen with marked hypopituitary characteristics, who had never menstruated, was admitted in 1952 with a slipped epiphysis of the left hip (Fig. 11).

In 1955, after two years as a fish-worker, she complained of painful wrists and was found to have a Madelung's deformity, due to growth arrest of the medial part of the lower radial epiphysis, with continued growth of the ulna (Figs. 12 and 13).

The following year she had genu recurvatum on the left side from fusion of the anterior part of the upper tibial epiphysis (Fig. 14).

Case 5—A girl of twelve was admitted to hospital in August 1950 with a slipped epiphysis which had given symptoms for nine months (Fig. 15). While in bed she complained of backache. A radiograph of the lumbar spine two months later showed wedging of the first lumbar vertebra (Fig. 16).

There was one other case of exactly similar wedging of the first lumbar vertebra, in a tall girl of fourteen, who was treated in hospital in 1947 for slipped epiphysis, and whose left patella was removed the following year for severe chondromalacia.

Case 6—A boy of fourteen was seen as an out-patient in March 1957, complaining of thoracic backache. This was found to be due to " osteochondritis " of the ninth thoracic vertebra (Fig. 17).

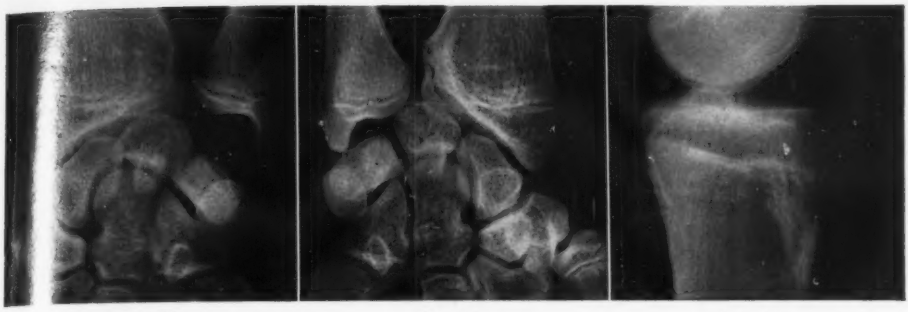

FIG. 12 FIG. 13 FIG. 14

Case —Wrists showing Madelung's deformity (Figs. 12 and 13) and left knee showing genu recurvatum (Fig. 14).

In July 1958 he was admitted to hospital with a slipped epiphysis of the left hip. Symptoms had been present for one month (Fig. 18). In November 1958 he complained of pain in the left ankle. There was slight swelling on the inner side of the ankle, and tenderness in the line of the joint. A radiograph showed a slight varus deformity. Fusion of the medial part of the epiphysis had occurred, but the epiphysial plate was still open laterally.

FIG. 15

FIGS. 15 AND 16

Case 5. Figure 15—This girl aged twelve had symptoms in the hip for nine months. She complained also of backache. Figure 16—The first lumbar vertebra shows wedging.

FIG. 16

Case 7—This patient, aged seventeen, had complained of pain in the right hip for nine months before admission to hospital in September 1958. A lateral radiograph (Fig. 19) showed a posterior slip. In this case the whole of the epiphysial plate was irregular, and growth of the front and back of the femoral neck were alike diminished, producing a shortening of half an inch which could not be explained by the degree of slip. In the thoracic spine (Fig. 20) there was diffuse epiphysial irregularity with wedging of several vertebrae.

Case 8—A boy aged fourteen was first admitted to hospital in September 1943, complaining of pain in the right hip of two weeks' duration. In addition to a slipped epiphysis he had a gross bilateral genu valgum, severe enough to be treated by supracondylar osteotomy.

In 1944 he developed a slipped epiphysis on the left side. For the next fifteen years he was able to work as a farm servant, although with increasing stiffness of the left hip. In April 1959 he was readmitted to hospital because of severe pain in the left hip. It was then noticed that he had a marked thoracic kyphosis. Radiographs showed old bilateral slipped epiphyses (Fig. 21) and wedging of several thoracic vertebrae (Fig. 22).

FIG. 17

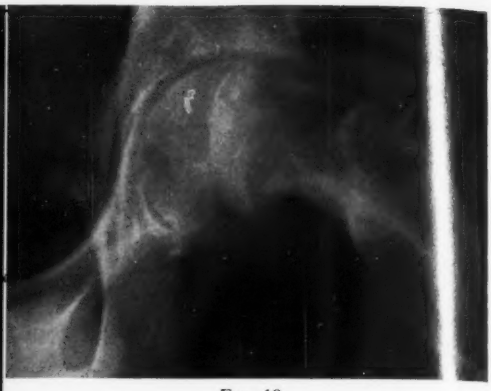

FIG. 18

FIGS. 17 AND 18

Case 6. Figure 17—A year after the diagnosis of osteochondritis of the ninth thoracic vertebra this boy was admitted with a slipped epiphysis (Fig. 18).

FIG. 19

FIG 20

FIGS. 19 AND 20

Case 7. Figure 19—The whole of the epiphysis of the left hip is irregular. Figure 20—There is also a diffuse irregularity in the epiphyses of the thoracic spine.

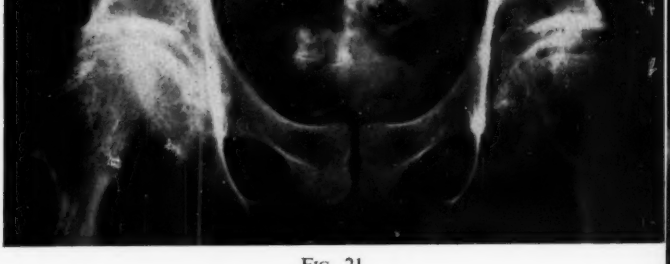

FIG. 21

FIG. 22

FIGS. 21 AND 22

Case 8. Figure 21—This man has old bilateral slipped epiphyses, and also a marked thoracic kyphosis (Fig. 22).

Routine radiographs of the spine of patients with slipped epiphysis have only been taken in recent months. Of the earlier patients, only those with backache had radiographs of the spine. Otherwise, it is probable that further examples of wedged vertebrae would have been found. The front of the vertebral epiphysial plate and the back of the epiphysial plate of the upper end of the femur are in one respect alike, both being exposed to severe compression forces.

Enough evidence has been adduced to show that, whatever the exact nature of the abnormality of the epiphysial plate of the upper end of the femur in slipped epiphysis, it is also commonly present in other bones. This is in keeping with the findings of Ponseti and McClintock (1956), who stated that "skeletal studies have shown widening and irregularities of other epiphysial plates which suggest that the lesion is not restricted to the upper portion of the femur," and that metabolic studies in cases of slipped epiphysis show an abnormality in protein metabolism similar to that found in "adolescent scoliosis."

One might indeed go further. If the cartilage of the epiphysial plate is abnormally sensitive to compression, is it not possible that articular cartilage may also, on occasion, be affected, and that early severe stiffness of the hip associated with a narrow joint space, but without increased density of the femoral head, may be due to this cause and not to avascular necrosis?

SUMMARY

1. Epiphysial tilt commonly precedes slipping.
2. This tilt is due to a diminished or arrested growth from compression of the back of the epiphysial plate.
3. The stresses on the upper end of the femur are such that the upper femoral epiphysial plate is peculiarly liable to compression.
4. A primary abnormality of the cartilage of the epiphysial plate renders it susceptible to the effect of compression.
5. Because this abnormality is diffuse, deformities due to a similar pathology may be found elsewhere, notably in the spine.

I am indebted to the other consultants of the Orthopaedic Service of the North-East region of Scotland for referring to me their cases of slipped epiphysis.

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THE SURGICAL TREATMENT OF SLIPPING OF THE UPPER FEMORAL EPIPHYSIS

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The treatment of slipping of the upper femoral epiphysis in adolescents occu es an interesting though frequently disappointing chapter in the history of orthopaedic s rgery. Repeated resort to manipulative or surgical methods, with the acknowledged dan rs to the hip, shows the underlying discontent with conservative treatment.

The indications for the different methods of treatment available have, in the pas been obscure, and the numerous reports in the literature have added to the confusion. Green 1945) advocated a method of conservative treatment and obtained excellent results in thirtee hips. Howorth (1949) reported excellent results in nearly all of 134 hips treated by placing bone pegs across the growth line. The operation was performed on twenty-nine occasions the pre-slipping stage. In most of the remaining 105 patients it seemed that the amount slip was minor. Wilson (1938) claimed good results with simple nailing in patients with a inor degree of slip. Klein, Joplin, Reidy and Hanelin (1953) found more than average succes with open reduction. Whatever method is used it is clear that the importance of an ade uate blood supply to the upper femoral epiphysis must be kept constantly to the fore; it i the most important factor in treatment. Only experience can show how easily it can be dam ged by carelessly planned, too vigorous or badly executed manoeuvres. Technique is of param ount importance.

CONSERVATIVE TREATMENT

Green (1945) evolved a careful method of conservative treatment. The patient was tre ted by traction in bed for a preliminary period of three to four weeks. Adhesive strapping was applied in a special way to give longitudinal traction combined with medial rotation. Traction began in the neutral position, and medial rotation and abduction were gradually increased according to the tolerance of the patient, but never enough to give pain. When the best possible position was obtained the hip was placed in a plaster spica for an average of three and a half months. Exercises in suspension and a period of walking with crutches gave a total of about fifteen months before the patient attained full activity.

Excellent as were the results in Green's series of thirteen hips, others have not met with similar success. The disadvantages of treatment by prolonged traction are numerous. There is the long period necessary to regain full activity, the accompanying disuse osteoporosis and muscle atrophy, potential stiffening of the hip joint and the frequent failure of this method to reduce the displacement of the epiphysis. It is doubted by many whether such treatment can reduce an epiphysis once it has become adherent.

Howorth (1949) quoted seven patients who were treated by heavy manual traction followed by immobilisation in plaster. Good correction was obtained in none and the resulting range of movement was poor in six cases.

Jerre (1950) gave the results in thirty patients with a severe degree of slip treated conservatively as " good " three, " fair " twenty-two and " poor " five.

It is debatable whether the little that can be achieved by conservative treatment is not outbalanced by the prolonged morbidity.

CLINICAL ASSESSMENT

This is a report on the clinical selection and treatment of slipping of the upper femoral epiphysis of sixty hips in forty-nine patients admitted since 1947. There were twenty-four boys and twenty-five girls. Eleven patients had a bilateral slip, six boys and five girls. At the

last follow-up the longest period since operation was eleven years and ten months, and the shortest seven months; the average time since operation was six years and one month. Clinical and radiographic assessment at the time of admission allowed all hips to be placed in one of three groups; in some patients with bilateral displacement the selection for each hip was

TABLE I
TYPES OF DISPLACEMENT

Type of displacement	Number of cases	Per cent
Group 1: position of epiphysis acceptable	39	65
Group 2: position of epiphysis unacceptable but epiphysis mobile	6	10
Group 3: position of epiphysis unacceptable and fixed . .	15	25

different: Group 1—position of epiphysis acceptable; group 2—position of epiphysis unacceptable but mobile; group 3—position of epiphysis unacceptable and immobile (Table I).

Group 1: position of epiphysis acceptable—An acceptable degree of deformity was defined by Wilson (1938) as less than one-third of the diameter in the lateral view. Klein, Joplin, Reidy and Hanelin (1953) defined it as less than one centimetre slip in each plane. In this series the assessment for acceptability was found to be obvious in most cases. In nearly all hips the degree of slip was either slight or severe, but in the few borderline patients acceptability was given a more liberal interpretation, especially if there was evidence of diminished blood supply to the epiphysis or degeneration of the joint cartilage.

FIG. 1
Subtrochanteric fracture sustained a year after simple nailing.

In every hip placed in group 1 the epiphysis was stabilised by internal fixation. This minor surgical procedure was given priority and performed forthwith without preliminary conservative or manipulative treatment.

Groups 2 and 3: position of epiphysis not acceptable—In the remaining patients the position of the epiphysis was unacceptable, and it remained to be ascertained whether the epiphysis was mobile so that the position could be improved. In some patients with a recent history of injury mobility was obvious, and in others the position was found to be changeable by replacement under anaesthesia or by traction. These hips, six in all, were placed in group 2.

In the remaining fifteen hips improvement was either unobtainable by examination under anaesthesia or traction, or considered unobtainable from the radiographic appearance and length of history. These were put in group 3.

TREATMENT

None of these patients was treated conservatively. When the position was acceptable, stabilisation was performed by internal fixation. When the position was unacceptable, an

attempt was made in some hips to improve the position either by replacement under anaesthesia or by sustained traction. In the remainder, intracapsular or subtrochanteric osteotomy was performed (Table II).

TABLE II

METHOD OF TREATMENT (SIXTY HIPS)

Simple stabilisation by internal fixation	39
Replacement under anaesthetic and internal fixation	5
Replacement by traction and internal fixation	1
Subcapital osteotomy	11
Subtrochanteric osteotomy	4

Stabilisation—In thirty-nine hips stabilisation was performed as the primary and only surgical procedure. In the first thirteen of these hips internal fixation was obtained with a trifin nail; and it is to be noted that nails of the usual adult size were used, a possible factor in the complications that arose. In two patients a subtrochanteric fracture of the femur occurred at the site where the nail penetrated the cortex (Fig. 1). In each case the fracture occurred a long time after the operation, when full activity had been reached. The injuries were insufficient to cause such damage in normal bone.

FIG. 2

FIG. 3

Figure 2—Stabilisation by Moore's pins. Figure 3—Stabilisation by modified pins.

This method of stabilisation with a trifin nail was abandoned, and the smaller type of pin designed by Moore was used. As a method of internal fixation it has proved to be satisfactory (Fig. 2). Two pins were used routinely, and in all patients the position of the epiphysis was held. The pins did not break or slip out, but did, on one occasion, cause erosion. This complication was later found to be due to a fault in manufacture. Difficulty arose when the time came for removal. Every pin was removed when fusion of the epiphysial line was confirmed radiographically. Great difficulty was experienced in this respect because of new bone formation in the thread of the pin; at times it was necessary to cut out a surrounding block of cortical bone to permit its removal. For this reason a new pin was designed, five inches long, sharpened at one end. It is circular in cross section, an eighth of an inch in diameter, but squared off for two inches from the blunt end to facilitate removal. It is made

of stainless steel and can be cut with strong wire-cutters to the desired length. This pin has proved entirely satisfactory and is still in use (Fig. 3).

The advantages of the small pin over the trifin nail are numerous. Small pins are easily inserted with minimal trauma to the bone and to the blood supply of the epiphysis. They enter the epiphysis without risk of its separation from the metaphysis at the time of penetration. They can traverse the cortex of the neck with ease, a considerable advantage in stabilising the more severe degrees of displacement.

Replacement under anaesthesia—Patients may be admitted with a history of recent injury followed by inability to bear weight on the affected limb; this, combined with the radiographic evidence of a loose epiphysis, leaves the diagnosis of acute traumatic displacement in no doubt. Such incidents may, or may not, be preceded by a history of limp or pain in the hip or knee, indicating some initial slipping before the acute displacement. In these acute injuries

FIG. 4

FIG. 5

Figure 4—Acute displacement of upper femoral epiphysis. Figure 5—Reduction and internal fixation of acute displacement shown in Figure 4.

replacement under anaesthesia is easy, although complete reduction may not be possible when slipping has been present before the accident. In other patients the epiphysis may be only partly loose and replacement more difficult, but nevertheless possible without force provided sufficient care and attention to detail are taken. With the patient relaxed under general anaesthesia the foot of the affected side is grasped, the knee flexed and the limb allowed to fall into medial rotation with the hip in slight abduction. Some preliminary traction in the long axis of the limb is permissible but no real force is used; rather should reduction be achieved by coaxing, not by strong manipulation. Manipulation in the treatment of slipped femoral epiphysis is a significant term and has been associated with bad results in the days when closed reduction by force was considered the correct method. For this reason the word manipulation has been avoided in this report in discussing the type of manoeuvre that was used. After replacement, either complete or incomplete, stabilisation is indicated under the same anaesthetic provided the position achieved is acceptable (Figs. 4 and 5).

Reduction by traction—Reports on the success of traction have been disappointing, but recently Hall (1957) suggested that results could be improved by attention to detail. In following up hips treated by different methods he found that traction in the neutral position between adduction and abduction with positive medial rotation gave the best results. This method was instituted in some patients, and undoubted improvement, sufficient to permit stabilisation, occurred in one hip. Traction was applied to both legs in order to avoid pulling in abduction. On the affected side skeletal traction, and on the opposite side skin traction was used. The skeletal pin on the affected side was employed to give vigorous and controlled medial rotation and was not used for heavy traction. Traction was applied for not more than two weeks.

FIG. 6

FIG. 7

Figure 6—Disappearance of joint space and necrosis of the epiphysis after subcapital osteotomy. Figure 7—A hip after subcapital osteotomy.

Subcapital osteotomy—In the last twelve years subcapital osteotomy has been performed in fourteen hips. Three patients on whom this operation was performed have been excluded from this report because a major operation on the same hip had been done before transfer for further treatment. The second operation failed to improve the functional result of the joint and in the light of later experience was almost certainly doomed to failure in each instance. The conclusion is that subcapital osteotomy will certainly fail in hips that are already stiff or showing signs of vascular depletion.

Subcapital osteotomy was achieved either by simple separation of the epiphysis from the metaphysis by cutting bridging bone where necessary, or by removal of a wedge of bone to help replacement. It was advantageous to start the operation with an incision over the lateral side of the base of the greater trochanter long enough for the insertion of the nail. This was driven up the centre of the femoral neck so that its point rested at the metaphysis.

Radiographic control was used during this stage but dispensed with subsequently. The hip was then exposed through an antero-lateral incision and the joint opened by an incision into the capsule parallel to the lip of the acetabulum. A further longitudinal incision of the capsule down the femoral neck was necessary in some instances. Osteotomy was performed with a thin curved osteotome, care being taken in cutting through the new bone on the postero-inferior aspect of the metaphysis. If necessary a wedge of bone was removed from the metaphysis to facilitate reduction of the epiphysis without force. Once the epiphysis was loose reduction was achieved with the aid of a specially shaped hook inserted into its metaphysial aspect and the leg rotated, flexed and abducted. When the epiphysis was in a good position the nail was easily driven across the epiphysial plate without further disturbance of the hip (Figs. 6 and 7). Care was taken to pass nothing between the cartilaginous surfaces in order to avoid damage to the artery of the ligamentum teres. The transcervical type of osteotomy was not performed.

Subtrochanteric osteotomy—Subtrochanteric osteotomy was the treatment of choice in four hips. Cuneiform biplane osteotomy, with the base of the wedge anteriorly and laterally, was performed just distal to the greater trochanter (Fig. 8). Internal fixation was used in two hips. In one patient, in whom the outer edge of the metaphysis was prominent, excessive bone was removed as a preliminary stage by an intra-articular operation after Heyman, Herndon and Strong (1957).

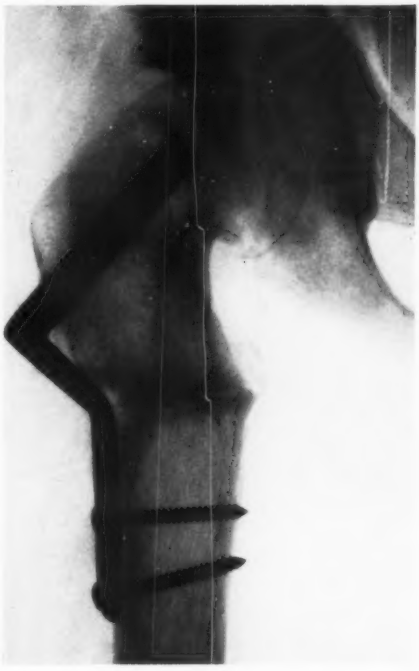

FIG. 8
Subtrochanteric osteotomy.

Management before and after operation—When the position of the epiphysis was acceptable, admission to hospital was advised forthwith and operation performed, not necessarily as an emergency, but as soon as reasonably possible. Non-weight-bearing exercises were begun on the following day and weight bearing was permitted after two weeks. A more cautious programme was planned for patients in whom the epiphysis was reduced. Non-weight-bearing exercises were begun one week after operation. Walking with crutches, without weight bearing on the affected leg, was allowed after one month, and walking without aid after three months.

When the position of the epiphysis was unacceptable and reduction not possible, operation was delayed to permit a period for active movements and hydrotherapy. This routine was designed to eliminate stiffness and to maintain or even improve the blood supply to the epiphysis and to the limb as a whole. After subcapital osteotomy the limb was immobilised in plaster for one month. During the second and third months after operation active exercises and hydrotherapy were encouraged. Weight bearing was allowed thereafter.

RESULTS

Most of these patients—forty-one hips in thirty-six patients—were examined and assessed by Hall during his report on the "Results of Treatment of Slipped Upper Femoral Epiphysis" for the British Orthopaedic Association (Hall 1957). The hips examined subsequently were assessed by the same method and comprised nineteen hips in thirteen patients. In giving

these later figures a slight modification has been made. Excellent and good results have been combined under the heading of good to bring the categories into ready comparison with other reports. There was another reason for this slight alteration. After simple nailing, when no attempt was made to reduce the epiphysis, the range of movement in most patients remained slightly restricted, although the operation had been satisfactory.

TABLE III

ASSESSMENT OF RESULTS*

	Patient's opinion	Pain	Function	Movement index *(per cent)*	Radiographic appearance of hip
Excellent	Normal hip	None	Unrestricted	Over 85 per cent of normal	Congruent surfaces, one-quarter diameter or less, viable head, good joint space
Good	Good hip, not quite normal	Does not interfere —ignores	Slightly restricted	75–85	Congruent surfaces, one-third diameter or less, viable head, good joint space
Fair	Gets some trouble	Stops some activities	Definitely restricted	50–75	Some irregularity, one-half diameter or less, lipping of head, narrowed joint space
Poor	Troublesome	Crippling	Poor function	Under 50	Joint space lost or necrosis of head

* Based on Hall's modification of Shepherd's method of assessment (1954).
The category selected is that of the worst feature.

"Poor" results—Among the patients in group 1 there were two poor results. The first occurred in a boy who had been treated by three months' traction in abduction to both hips. Stabilisation with a trifin nail was performed on one side and subcapital osteotomy on the other. Both gave a poor result. This was one of the early cases, and too little account was taken of the stiffness and slight diminution in joint space before operation. These findings would now be considered contra-indications to surgical treatment.

TABLE IV

TOTAL RESULTS

Operation	Excellent or good	Fair	Poor	Total
Simple internal fixation	37	0	2	39
Reduction and internal fixation	6	0	0	6
Subcapital osteotomy	6	1	4	11
Subtrochanteric osteotomy	3	1	0	4
Total	52	2	6	60

The other patient had a mild degree of slip and was successfully treated by pinning with two small pins. These pins subsequently slipped. The patient had a fall and redisplaced her epiphysis. By the time she was seen again the epiphysis had become stabilised in an unacceptable position. Further surgery was thought unwise, but subtrochanteric osteotomy may be performed later.

Among the six hips that were reduced by closed methods before stabilisation there were no poor results. Of the eleven patients treated by subcapital osteotomy four achieved a poor

result. One was the patient mentioned above, who was admitted after a long period of traction in abduction. The other three were unsuccessful for no obvious reason. Two of these patients had a good result initially, but within a year showed decreasing range of movement and diminishing joint space. The other developed a frank aseptic necrosis of the epiphysis.

Among four patients who had a subtrochanteric cuneiform osteotomy one showed marked stiffening after the removal of plaster. This did not respond to exercises for some time but is now improving. It has been helped by three gentle manipulations under anaesthesia.

DISCUSSION

The simple, safe and valuable procedure of fixation by pin, which in this series was possible in 7 per cent of cases, is still confused with the more hazardous operations of open reduction by osteotomy. It is not yet universally accepted that the condition is a surgical emergency, for there is delay on all counts in making the diagnosis and often delay in disposal once the diagnosis has been made. In this group of patients, all of whom were treated surgically, there was an average delay of 26·6 weeks from the initial onset of symptoms until the day of operation. Most of the delay occurred before the symptoms were reported to the patient's family doctor or school medical officer, but in addition to that there was delay in clinical diagnosis, and often, in this series of seven cases, a false radiographic reassurance because of the lack of lateral views. Once the diagnosis had been made there was still a delay of 3·8 weeks before operation was performed. This time was lost in awaiting out-patient appointments, awaiting a bed or transfer from one hospital to another (Newman 1958). It seems rational now that the profession should regard slipped femoral epiphysis as a surgical emergency, no matter the degree of the slip or the mildness of the symptoms. A slight slip should be fixed, an acute displacement reduced and fixed, and a major displacement subjected to closed reduction unless bony fusion is present. A major deformity that is irreducible no longer demands priority of treatment but presents a problem for assessment and maintenance of function. The surgical treatment of patients in this category is a difficult problem and is essentially a procedure of salvage.

Subcapital osteotomy can give good results in about two-thirds of patients, but because of loss of hip function in the remainder it cannot be considered a safe or acceptable operation. Subtrochanteric osteotomy is indicated when the epiphysis has fused with severe deformity. It does not give a good anatomical result but functionally at least most patients can be expected to gain a satisfactory hip. A cuneiform osteotomy with the base of the wedge antero-laterally is performed obliquely between the trochanters. This gives a correction into flexion, abduction and medial rotation. A special pin has been made which can be easily inserted without radiographic control to hold the fragments in the corrected position. This pin is not designed to give sufficient fixation to allow early walking without plaster, nor is it meant to cross the epiphysial line to promote fusion as this is probably unnecessary and would necessitate careful radiographic control.

Five patients have been treated in this way during the last year with apparently good results, but the time since operation is insufficient to warrant their inclusion in this report. In one case the range of movement was improved by removal of the prominence of the outer aspect of the metaphysis (Heyman, Herndon and Strong 1957).

CONCLUSIONS

Simple pinning to fix the epiphysis in those patients in whom the position is acceptable is a valuable surgical procedure. It is safe and gives good results. It eliminates the danger of further displacement, promotes fusion of the epiphysial plate and allows the patient to return to full activity within one month, thus avoiding joint stiffness, muscle atrophy, osteoporosis and interference with growth at other sites.

Fixation by small pins is preferable to the use of the trifin nail, the latter giving excessive trauma and predisposing to subtrochanteric fracture. Gentle replacement of the epiphysis, when loose, into an acceptable position is a valuable method of treatment. It is essential that replacement is not undertaken by force.

The problem of major displacement of the epiphysis which cannot be so replaced is unsolved. Conservative treatment in this group is useless and harmful. Intra-articular osteotomy can give good results in most cases but is risky and may cause stiffening of the hip. Subtrochanteric osteotomy does not give a good anatomical result but in most cases the function of the hip is satisfactory.

Slipping of the upper femoral epiphysis, however slight, should be regarded as a surgical emergency.

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TREATMENT OF SLIPPED UPPER FEMORAL EPIPHYSIS

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Slipping of the upper femoral epiphysis has been recognised since 1572 when it was first described by Paré, but its cause has not yet been fully determined. Treatment has been a controversial subject since the late nineteenth century when operative measures were first practised. The pendulum for and against operation has been swinging ever since, with a bias towards conservative treatment.

The condition is relatively uncommon and therefore the collected results of a large series are valuable. After a study of slipped femoral epiphysis carried out by a sub-committee of the British Orthopaedic Association, Hall (1957) reported on the results of all forms of treatment in 173 hips in 138 patients representing a random sample of the results in the United Kingdom in recent years. The results of a previously unreported series of eighty-one hips in sixty-three patients are presented here (Table I). The series is comparable to Hall's except that all hips have been compared with a standard of normal mobility of 85 (Gade's indices). Although Gade produced an index of 100 for a normal hip Hall estimated it to be 90 in fifty normal hips and we found it to be 85. Assessment of functional activity followed Hall's modification of Shepherd's (1954) plan (Table II).

The results in the series as a whole are comparable with those found by Hall (1957) (Table III, Fig. 1).

TABLE I

ANALYSIS OF MATERIAL STUDIED

63 patients		81 hips	
Male	38	Involvement left hip	47
Female	25	right hip	34
		both hips	18
Longest follow-up			22 years
Shortest follow-up			1 year
Average			6·5 years

CONSERVATIVE TREATMENT

Failure to prescribe treatment might be considered negligent; yet, as Howorth (1957) has reminded us, we carry a heavy responsibility when we undertake treatment. The condition always heals without treatment and the results in untreated hips are often good, for avascular necrosis seldom occurs and disability before middle life is rare.

In very early cases further slipping can be prevented by rest in bed, plaster splintage or the use of a walking caliper. Such treatment must be prolonged because the epiphysis may not fuse for several years, and, until fusion has occurred, further slipping is possible. Slipping recurred three times in the present series after conservative treatment—once eighteen months after primary treatment had ceased. If prolonged, plaster splintage may lead to restricted mobility of the hip; and it promotes chronic invalidism and interferes seriously with the child's education at an important stage when examinations may be approaching. Furthermore, conservative treatment may fail and lead to an imperfect result (Table IV).

Formerly, hips with unacceptable degrees of displacement have been forcibly manipulated or treated with powerful traction regardless of the duration of symptoms. There is no doubt

TABLE II

SUMMARY OF FACTORS CONSIDERED IN ARRIVING AT A FINAL ASSESSMENT
(Modified from Shepherd and Hall)

	Pain	Index of mobility	Function by performance	
Excellent	None or ignores	Over 80	1 black mark	Incongruent joint surfaces, gross displacement, osteoarthritic lipping or narrow joint space caused hip to be placed in a sub-category with poorer prognosis
Good .	None or ignores	70–80	Up to 3 black marks	
Fair .	Concessions	45–70	Up to 5 black marks	
Poor .	Disabling	Under 45	6 or more black marks	

TABLE III

RESULTS IN THE SERIES AS A WHOLE, COMPARED WITH THOSE FOUND BY HALL

	Present series	Hall's figures
	Percentages	
Excellent	39·6	48·3
Good .	35·8	29·6
Fair .	12·3	6·9
Poor .	12·3	15·2

TABLE IV

CONSERVATIVE TREATMENT: RESULTS IN NINETEEN HIPS

	Present series	Hall's figures
	Percentages	
Excellent	37	35·5
Good .	37	39·9
Fair .	5	12·3
Poor .	21	12·3

TABLE V

EFFECTS OF MANIPULATION ON ALL TREATMENT EXCLUDING OSTEOTOMY
Hall's figures are in bold type

	Excellent		Good		Fair		Poor	
	Percentages							
With manipulation . 28 hips	43	**27·2**	18	**45·4**	21	**18·2**	18	**9·1**
Without manipulation 32 hips	56	**43·8**	44	**34·4**	0	**6·3**	0	**15·6**

TABLE VI

SUBLUXATION OF HIP RESULTING FROM TRACTION

Abduction frame	1
Skin traction	1
Skeletal traction	2
Total . .	4

that hips which have been manipulated present worse results than those which have not, whatever the subsequent treatment may be (Table V, Fig. 2). Manipulation must be gentle if it is used at all.

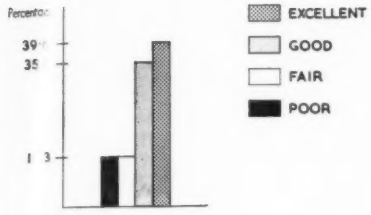

FIG. 1

Results in the whole series of eighty-one hips in sixty-three patients.

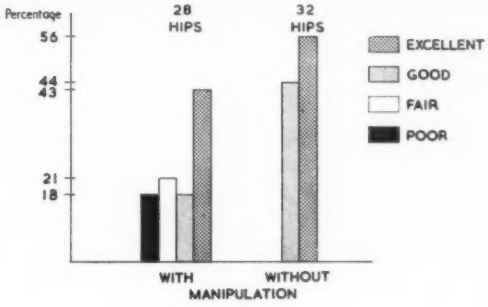

FIG. 2

Results of treatment with and without manipulation.

Traction must be used with care because the hip may be subluxated or dislocated, especially by skeletal traction and even with skin extension or with traction on an abduction frame (Table VI, Figs. 3 and 4).

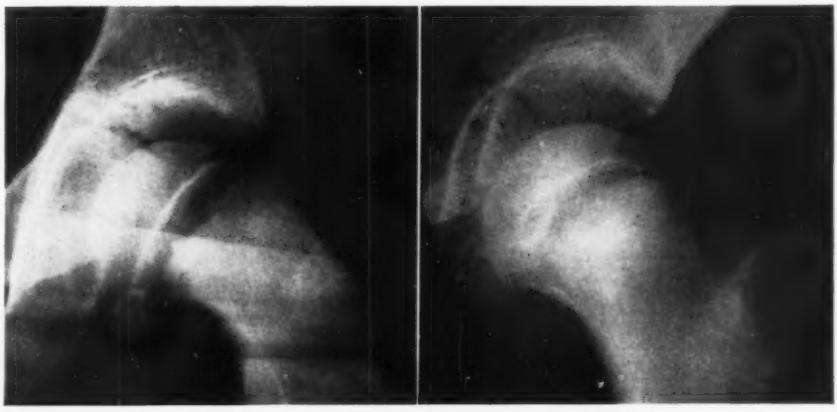

FIG. 3 FIG. 4

Figure 3—An acute slip of the left epiphysis. Figure 4—Reduction achieved by straight traction for twelve hours, but subluxation of the head of the femur has occurred.

OPERATIVE TREATMENT

The early literature of this has been extensively reviewed by Howorth (1957). In the days before radiography, correction of the deformity by a subtrochanteric osteotomy had been obtained by Keetley (1888) and Bradford (1892). Sturrock in 1894 used internal pin fixation of the epiphysis but the result was a failure. Later, Whitman (1909) reported a series of eight cases of open reduction of the slipped epiphysis. Ferguson and Howorth (1931) drilled holes through the epiphysial plate and inserted small bone grafts into them in order to promote quick fusion of the epiphysis to prevent further displacement. They also reported on the pathology of bone and synovial material removed by them at the time of operation.

Wilson (1938) recognised that there were two main groups of patients—those with minimal displacement and those with advanced deformity. Patients treated early obtained excellent results and therefore their early recognition was important. He advised immediate fixation of the epiphysis by insertion of a Smith-Petersen nail. Then Klein, Joplin and Reidy (1948) led a revival of open reduction by cervical osteotomy combined with Smith-Petersen nailing.

FIG. 5
An early slip of the right epiphysis, and the normal left hip for comparison.

FIG. 6

FIG. 7
Lateral radiographs of the same hips as in Figure 5 showing the degree of displacement of the right epiphysis.

Their high proportion of successful results has not been confirmed and this procedure is now seldom performed. All observers are agreed that when the slip is of long standing any form of treatment is a salvage procedure.

Unquestionably the best results are by treatment of the minimal slip at an early stage, the epiphysis being fixed so that it can displace no further. This necessitates better education

of the family doctor in the early symptoms and signs, for many patients have symptoms for several months before the diagnosis is made at hospital. Howorth's view is that to diagnose the early case it is most important to think of the possibility, examine the hip carefully and obtain good radiographs.

FIG. 8

An early slip showing the characteristic "beak" appearance of the epiphysis. The so-called step up from the neck of the femur to the epiphysis is still present.

The radiographic diagnosis is not always easy, especially when the epiphysis is displaced backwards and not medially, as it may be missed in the antero-posterior view (Figs. 5 to 7). In the early case there is a characteristic beak-like appearance of the inferior angle of the slipped epiphysis at its junction with the inferior surface of the neck of the femur (Fig. 8).

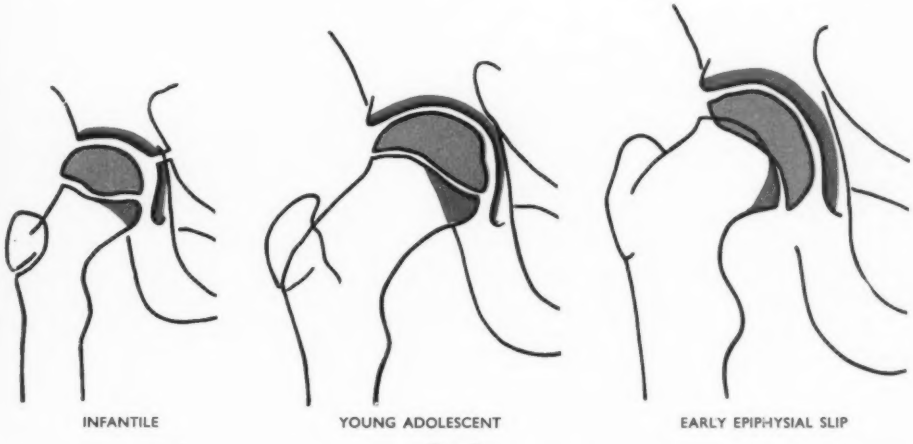

FIG. 9

Diagram showing how the diaphysis extends medially under the epiphysis, forming part of the articular femoral head in the infant and young adolescent. The exclusion from the acetabulum of this articular portion of the diaphysis by the downward and backward thrust of the epiphysis is one of the earliest radiological signs of adolescent slipping of the upper femoral epiphysis (Capener 1956). The downward pointing epiphysial beak is apparent even when the displacement is less than that shown in the drawing. Blue—The morphological capital epiphysis. The acetabulum and diaphysial contribution to the adult articular head are red.

TABLE VII

COMPARISON OF RESULTS OF CONSERVATIVE TREATMENT, SMITH-PETERSEN NAILING AND MULTIPLE PINNING
Hall's figures are in bold type

	Excellent		Good		Fair		Poo	
	Percentages							
No operation—19 hips	37	**35·5**	37	**39·9**	5	**12·3**	21	**13**
Nailing—14 hips	57	**68·9**	22	**18·8**	14	**4·2**	7	**4**
Multiple pinning—27 hips	52	**80**	37	**20**	11	**0**	0	

It is not sufficiently realised that the caput femorale comprises more than the capital epiphysis. The diaphysis extends medially under the epiphysis and forms part of the articular femoral head. Capener (1956) has shown that the exclusion from the acetabulum of this articular part of the diaphysis by the downward and backward thrust of the epiphysis is amongst the earliest radiological signs of slipping (Fig. 9).

Treatment in cases with slight displacement—When a slight displacement has been recognised the epiphysis should be fixed surgically as Wilson (1938) advised. The Smith-Petersen nail, however, has certain disadvantages: its large bulk may sometimes render its insertion difficult. The healing reaction at the site of the slip tends to prevent the entry of the bulky nail as it reacts like rubber and diminishes the force of the hammer blow besides causing resistance.

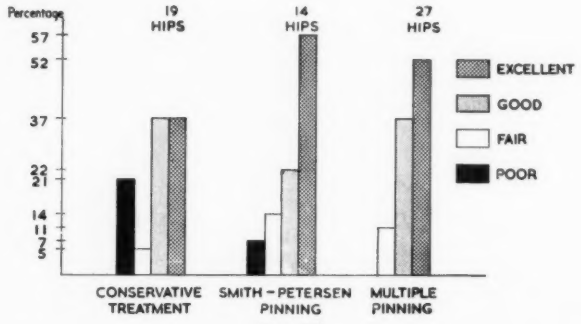

FIG. 10

Results of conservative treatment, Smith-Petersen nailing and multiple pin fixation.

Forcible hammering under such circumstances may lead to further trauma and displacement of the epiphysis. Hall (1957) mentioned the large number of complications which result from the use of a Smith-Petersen nail. Wiberg (1959) has been more successful with the smaller Nyström nail but it too has its disadvantages. Newman (1956) reported the results in a series of cases in which multiple pins of the Austin Moore type were used. Multiple pins have also been employed at Exeter since 1950. A high proportion of successful results has been obtained (Table VII, Fig. 10). These pins can be inserted without much trauma, as little force is required to hammer them in and they will hold the epiphysis much in the same way as the crampons of a mountaineer's boots hold him on a slippery icy slope. Three or four are used and careful radiological technique is necessary to insert them. The relative ease with which a pin of small diameter can be inserted may be demonstrated by pushing i

into a sorbo rubber ball. It will be found impossible to introduce a Smith-Petersen nail into the ball either by pressure or by hammering.

The pin needs a thread and nut at the end to prevent further penetration. It is, however, important that the thread is not continued far down the pin as this may make extraction difficult at a later date.

Internal fixation permits ambulation within four weeks of operation and weight bearing may be permitted at eight weeks. Fusion of the epiphysis has usually taken place within six to twelve months.

FIG. 11

Showing the anterior superior bony ridge in a pinning with more than 50 per cent displacement. Three years after pinning.

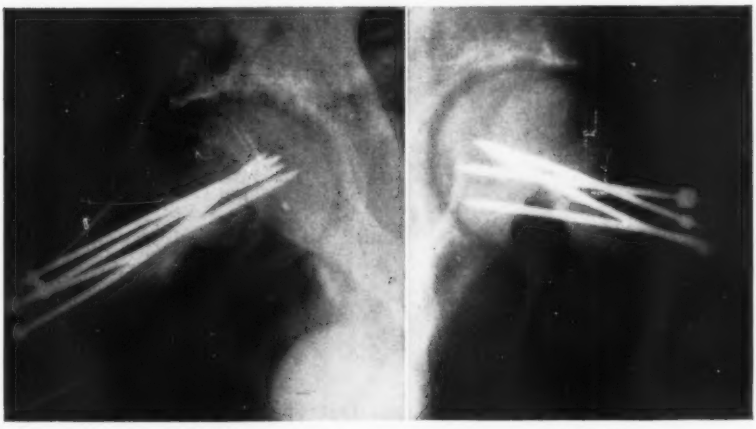

FIG. 12 FIG. 13

Lateral views of the same hip joints as in Figure 11.

Treatment in patients with marked displacement—Pinning in the position of displacement should not be performed if the femoral head has slipped more than half its diameter because a bony ridge may develop at the antero-superior aspect of the neck which will limit abduction and medial rotation (Figs. 11 to 13), and lead to osteoarthritis later. Heyman, Herndon and Strong (1957) revived a conservative operation described by Elmslie (1913) to remove this bony prominence in the established case but the value of this procedure is doubtful because osteoarthritis may still occur in later years.

When there is very marked displacement a gentle manipulative reduction should be attempted. If this is successful the epiphysis is fixed with three or four pins. If no alteration in position is possible it is best to perform an osteotomy in the trochanteric region, because it is unlikely that the epiphysis can be replaced by either more powerful manipulation or traction without endangering its blood supply and thus producing a poor result. The latter may already be inevitable because of interference with the blood supply caused by the original slip. It is not sufficiently well known that the epiphysis of the femoral head at this age is particularly susceptible to avascular necrosis, because of its precarious circulation, and that

TABLE VIII

RESULTS OF OSTEOTOMY

Hall's figures are in bold type

	Excellent		Good		Fair		Poor	
	Percentages							
Cervical—9 hips	11	**23·7**	22	**35·7**	11	**4·7**	56	**35·8**
Trochanteric—12 hips	17	**22·2**	58	**33·3**	25	**22·2**	0	**22·2**

this complication is common after fractures of the neck of the femur in children, even after fractures without displacement (Durbin 1959). Its frequency after an operation such as cervical osteotomy is therefore not surprising. Four out of nine of the hips in our series subjected to this operation developed avascular necrosis, and the procedure is therefore to be condemned.

The unacceptable immobile position or established coxa vara may cause disability with limitation of abduction and medial rotation of the hip. Any form of treatment is then a

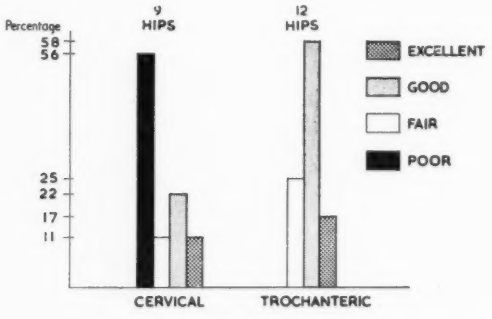

FIG. 14
Results of osteotomy.

salvage procedure. The disability can be minimised by correcting the deformity of abduction and lateral rotation and restoring the arc of movement by wedge osteotomy in the trochanteric region. This procedure was revived by Perkins (1932). Intertrochanteric and subtrochanteric osteotomy appear to be equally successful, though in view of the displacement of the epiphysis the osteotomy should be low. After such corrective osteotomies remarkable remodelling occurs and some unpromising hips have gone on to present very successful results (Table VIII. Figs. 14 to 18).

radiographs many years afterwards (in one case twenty-two years) reveal a hip with an excellent "joint space" and in this respect the results are similar to the effect of displacement osteotomy on certain osteoarthritic hips. After osteotomy the leg should be placed in about 45 degrees of abduction as this ensures that the new bone formed between the epiphysis and

FIG. 15

FIG. 16

Figure 15—A severe long-standing slip in a boy aged thirteen. Figure 16—Three months after trochanteric osteotomy and immobilisation in a plaster spica.

FIG. 17

FIG. 18

Figure 17—Eight months after operation. There is remoulding of the neck of the femur. Figure 18—Fifteen years after operation there is normal movement in the hip joint. Further remoulding has occurred.

the neck of the femur will not be in contact with the acetabular rim when the leg is in the normal walking position after union of the osteotomy. Failure to do this may lead to the formation of a bony ridge resulting in restricted movement and the later development of osteoarthritic changes.

Avascular necrosis—Avascular necrosis occurs in two forms (Table IX)—massive necrosis of the epiphysis with preservation of a good joint space and acute necrosis of articular cartilage with diminution of the joint space (Waldenström 1930, Moore 1945, Jerre 1950, Lowe 1959).

FIG. 19

A severe slip in a patient who had symptoms for three years. Skeletal traction was applied and subluxation of the hip resulted but the position of the epiphysis was unchanged. A subtrochanteric osteotomy was performed.

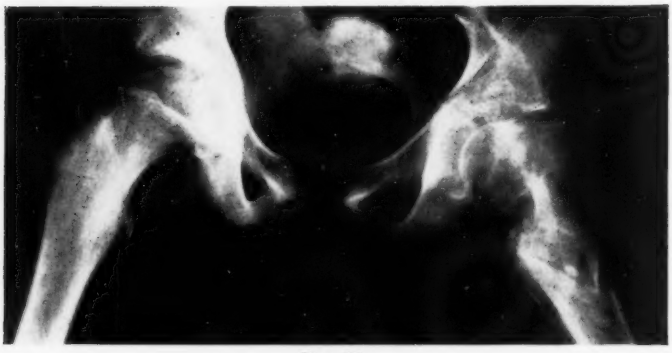

FIG. 20

Three months after subtrochanteric osteotomy, showing about 35 degrees of abduction at the site of osteotomy.

FIG. 21

Six months after the operation on the left hip there was sudden pain in the right hip and radiographs showed slipping of this epiphysis. The patient was walking without support at this time.

FIG. 22
Reduction of the displacement was achieved by manipulation, and plaster spica fixation for three months was employed.

FIG. 23
Four years later. The left hip is excellent, but there are signs of deterioration in the right hip joint and cystic changes are present in the neck of the femur.

FIG. 24
Thirteen years after the onset of symptoms. The left hip joint is excellent but degenerative changes are present on the right side.

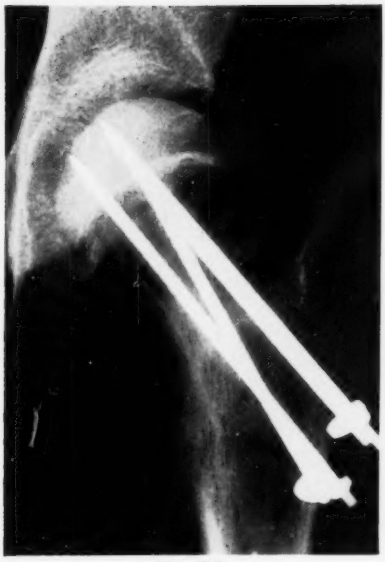

FIG. 25

FIG. 26

Antero-posterior and lateral radiographs two months after reduction and multiple pinning; the epiphysis shows relative density suggestive of avascularity. A weight-relieving caliper was applied and worn for two years.

The first group has a better prognosis than the second, in which an ankylosed hip frequently results (Table X, Figs. 19 to 24).

The two patients with avascular necrosis after insertion of multiple pins were provided with walking calipers which were worn for two years. Excellent revascularisation of the epiphysis took place in both (Figs. 25 to 28).

FIG. 27

FIG. 28

Four years after pinning. Radiographs show an almost normal epiphysis. There is full range of joint movement.

TABLE IX

TYPE OF NECROSIS

Type of necrosis	Cervical osteotomy	Manipulation and plaster	Manipulation and Smith-Petersen nailing	Manipulation and multiple pins	Result
Necrosis of epiphysis	—	1	1	2	2 good 1 fair 1 poor
Necrosis of cartilage	4	1	1	—	1 fair 5 poor

TABLE X

RESULTS IN TEN HIPS WITH AVASCULAR NECROSIS

(12·3 per cent of series—compare Hall's 15·6 per cent)

Treatment	Number of hips	Results			Remarks
		Good	Fair	Poor	
Cervical osteotomy	4			4	All ankylosed
Manipulation and plaster . . .	2		1	1	
Manipulation and Smith-Petersen nailing	2		1	1	
Manipulation and multiple pinning .	2	2			Subluxation nailing was caused in one patient by skin traction without medial rotation of the hip
Total	10	2	2	6	

DISCUSSION

It is possible to outline a scheme of treatment based upon the deductions drawn from this investigation. 1) Conservative treatment should be rejected because of its uncertain results. 2) When the condition is recognised at the stage of an acceptable amount of displacement the epiphysis is fixed with three or four pins. The patient rests in bed for four weeks after operation. Partial weight bearing is then allowed. Full weight bearing is permitted at the end of two months. 3) When recognition is delayed until the stage of an unacceptable amount of displacement (half diameter or more) the hip is *gently* manipulated under general anaesthesia. If reduction is achieved then three or four small pins are inserted. No weight bearing is allowed for two months. 4) When gentle manipulation fails to reduce such a displacement the deformity is corrected by trochanteric osteotomy. Intertrochanteric wedge osteotomy is easier to control than subtrochanteric. This operation restores the arc of movement and corrects the deformity of adduction and lateral rotation. If the slip is severe, wide abduction of about 45 degrees is required after osteotomy and it is an advantage if the limb is immobilised in plaster in flexion to bring the shaft of the femur into line with the posteriorly displaced epiphysis. A double spica is necessary for about three months.

SUMMARY

1. A series of eighty-one hips with slipped upper femoral epiphysis in sixty-three patients is reviewed.
2. The importance of early diagnosis is emphasised.
3. Conservative treatment is condemned.
4. In attempting reduction violent manipulation and strong traction must be avoided.

5. In cases of slight displacement pinning in the position of displacement gives the best results.
6. Three or four small pins are recommended for fixation.
7. When the amount of slip is 50 per cent or more of the diameter of the head gentle manipulation should be tried and, if successful, followed by fixation with three or four pins.
8. The hip with an irreducible slip of 50 per cent or more should be treated by pertrochanteric or subtrochanteric osteotomy.

I wish to thank my colleagues at the Princess Elizabeth Orthopaedic Hospital, Exeter, for permission to include their cases, and Mr Leon Henry for three cases treated by intertrochanteric osteotomy. I am also much indebted to Mr James Piggot who assisted in the review of the patients.

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ALBERS-SCHÖNBERG'S DISEASE

A Changing Concept

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In 1904 Albers-Schönberg first described the radiological appearance of marble bones. His subject was a healthy merchant aged twenty-six years who had sustained abnormal fractures since childhood. He was found eleven years later by Reiche (1915) still to be leading a normal life, although he had hepato-splenomegaly and his haemoglobin was about 30 per cent.

In the ensuing years Albers-Schönberg's disease, named osteopetrosis by Karshner (1926), came to be regarded principally as a grave and progressive disorder of infancy. A fulminating form is manifest from birth, in which fractures and deformity, hydrocephalus and cranial nerve palsies lead to early death from intractable anaemia and intercurrent infection. In other cases the stigmata are delayed until later childhood, when retardation of growth and of mental and sexual development occurs, not infrequently accompanied by rickets, dental caries and osteomyelitis. Although the parents may be consanguineous, this " malignant " disease is sporadic and seldom familial; nor are milder variants found in the same family.

In 1923 Alexander reported the findings in a woman of forty-three years—the first record of the disease in English and the second adult case to be described. The patient, whose parents were cousins, had no hepato-splenomegaly, but her haemoglobin was 45 per cent and she was prone to fractures.

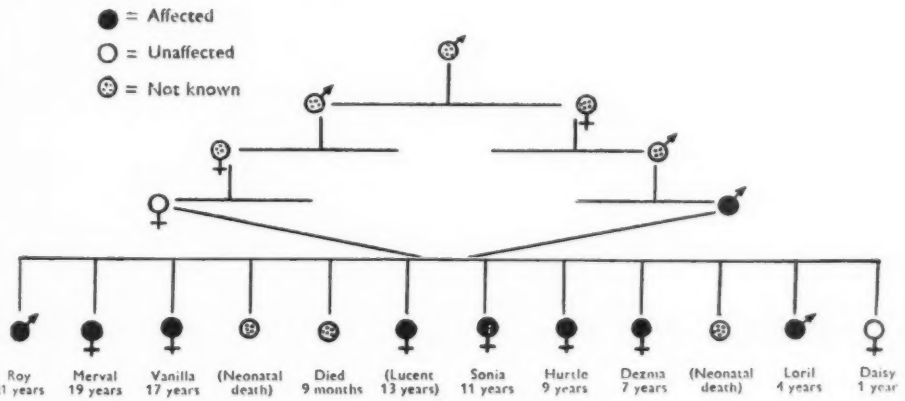

FIG. 1
Relationships of the affected family.

With the expansion of radiological exploration have come a number of comparable descriptions of adult disease, in which it is now possible to define a common pattern. The clinical findings of twenty writers including Albers-Schönberg have been summarised by Hinkel and Beiler (1955). Their picture is that of a benign osteosclerotic disorder encountered at all

ages and in all races, which may remain symptomless or may reveal itself by abnormal fractures. Anaemia is found in less than half of the cases and hepato-splenomegaly is rare. Radiologically the bones of the pelvis are always affected, the long bones nearly always, and the bones of the extremities, the skull base and vertebrae commonly. The blood chemistry is normal. The condition is strongly familial in one generation, and at least a quarter of the parents are consanguineous.

To this literature may be added the following nine members of one family, who reveal certain deviations from the common pattern.

FIG. 2

FIG. 3

Vanilla.

CASE REPORTS

Clinical findings—The patients were encountered by one of us (K. L. S.) during a field survey of a country population in Jamaica. Particulars of the family are shown in Figure 1. The father, a farmer, and the mother, who was his second cousin, were of Negro stock. They had had twelve children, nine of whom were alive, and all of whom were of both parents. All deliveries had been uneventful and the developmental milestones of the surviving children had been normal. Three of them—Vanilla (aged seventeen), Hurtle (aged nine) and Dezma (aged seven)—were found to have a facial nerve palsy (two left-sided, one right-sided) which in each case had developed acutely at the age of six.

Hurtle and Dezma revealed no other clinical abnormality. Vanilla in addition gave a history of deterioration of vision for about eight years, followed soon after by bulging of the eyes and a chronic nasal discharge. She had had generalised headaches for several years, associated with spells of giddiness and increasing weakness of the limbs. Examination showed bilateral optic atrophy with total blindness of the right eye and perception of light on the left, with proptosis, more marked on the right, and slight chemosis. There was a constant snuffle due to a serous discharge from the left nostril, which was almost blocked. Overgrowth

of the facial bones and mandible gave a flattened facial appearance with frontal prominence, relatively small upper lip and broad nasal bridge (Figs. 2 and 3). The only other physical abnormalities were thoraco-lumbar scoliosis and exaggeration of the knee-jerks. Mentally she was placid and apathetic, but of average intelligence.

This patient was admitted to hospital where radiography revealed a form of osteopetrosis, and other investigations were done as outlined below. Lumbar puncture revealed normal fluid under a pressure of 200 millimetres, protein 20 milligrams per cent, cells 1 per cubic millimetre, V.D.R.L.*—negative. Queckenstedt's test was negative. The blood urea was 28 milligrams per cent, and urine analysis and Sulkowitch test were normal. Audiometry revealed no defect of hearing.

Subsequently all the other members of this family were examined and investigated. There was a strong tendency in the siblings to a similar facial appearance (Fig. 4). No other physical abnormality was found; they were all of average nutrition with an average amount of dental caries, and there was no hepato-splenomegaly or lymphadenopathy. In their district the fluoride content of the water was unusually low (0·02 parts per million).

FIG. 4
Hurtle.

Laboratory findings—The results are summarised in Table I. There was no significant anaemia, and red cell studies in each case showed only mild hypochromia. The differential cell counts were normal, and the serum calcium and phosphorus were also within acceptable limits.

The levels of alkaline phosphatase were raised in all except one of the children and must be considered slightly abnormal even in relation to their age. It is of interest that in the case of Sonia the radiological evidence of disease appeared subsequently. As a random check, alkaline phosphatase tests were repeated on Hurtle and Dezma three months later and gave values of 34 and 44 units respectively. This rise is in no way reflected in the other liver function tests, the values of which are all within the range normally found in the Jamaican community—including the figures for choline esterase (Garrow 1954) which are taken as a delicate index of hepatic cellular function. Alkaline phosphatase estimations in a small series of healthy Jamaican children aged three to eleven, carried out in the same laboratory, have shown a maximum level of 33 King-Armstrong units, and an average figure of 21 units.

There was no evidence of syphilis except in the case of the mother. The incidence of positive serology in the population is over 20 per cent, and is in some instances attributable to yaws. Several of the family had ascaris and trichuris infection but there was no evidence of hookworm.

Radiological findings—The following changes were found on initial examination in August 1957. *Vanilla* (aged seventeen)—All the bones of the skull showed dense sclerosis and thickening with obliteration of mastoid air-cells and frontal sinuses (Fig. 5). The orbital cavities were reduced and coned views demonstrated narrowing of both optic foramina. There was uniform

* The standard cardiolipin test of the United States Venereal Diseases Reference Laboratory.

TABLE I

INVESTIGATION OF THE AFFECTED FAMILY

	Mother	Father	Roy	Merval	Vanilla	Lucent	Sonia	Hurtle	Dezma	Loril	Daisy
Age (*years*)	39	42	21	19	17	13	11	9	7	4	1
Clinical abnormality	–	–	–	–	++	–	–	+	+	–	–
Radiological abnormality	–	+	++	+	++	+	±	+	+	+	–
Haemoglobin (*grammes*)	12·8	15·7	14·2	12·1	11·7	13·0	13·1	12·0	11·8	11·	
24-hour sickling	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg	
V.D.R.L. test	+1:16	Neg.			Neg.		Neg.	Neg.	Neg.		
Serum calcium (*milligrams*)	10·8	10·0	9·8	10·3	11·1	10·6	11·2	10·7	10·8	11·(	
Serum phosphorus (*milligrams*)	3·0	3·5	5·1	4·9	3·5	6·3	4·3	4·3	5·3	5·2	
Alkaline phosphatase (*K.-A. units*)	7	14	22	8	17	34	32	39	44	30	
Serum bilirubin (*milligrams*)	1·0	1·7	0·7	V.N.*	0·2	V.N.*	V.N.*	V.N.*	V.N.*	V.N.	
Thymol turbidity (*units*)	2·1	1·2	1·1		3·8	1·1		2·7			
Serum protein (*milligrams*)	8·4	7·8	7·6	7·4	7·4	7·6	8·7	7·3	6·8	7·5	
Albumin (*grammes*)	3·9	3·6	4·1	3·8	3·7	4·0	3·7	2·8	2·8	3·6	
Globulin (*grammes*)	4·5	4·2	3·5	3·6	3·7	3·6	5·0	4·5	4·0	3·9	
A:G ratio	0·9	0·9	1·1	1·1	1·0	1·1	0·7	0·6	0·7	0·9	
Serum cholinesterase (*units*)	0·7	0·5	0·4	0·6	0·6	0·6	0·5	0·5		0·6	

* V.N. = visually normal.

The figures for albumin and globulin are within the limits of normal for the West Indies.

sclerosis of the ribs, vertebrae and pelvis (Figs. 6 and 7). The bones of the limbs were considerably involved; in the femora sclerosis was greatest in the middle and uppermost thirds, with cortical thickening at the expense of the medulla and with slight distortion of outline. There was generalised thickening of trabeculae progressing in the most severely affected bone through a granular appearance to complete hazing.

Roy (aged twenty-one)—Similar changes were present in the same bones to a comparable degree. The mastoid air-cells were obscured. The femora were more extensively involved, with thickening of the whole shaft (Figs. 8 and 9).

Merval (aged nineteen)—There was mild generalised involvement, most marked in the pelvis. Changes in the base of the skull were more obvious than in the vault (Figs. 10 and 11).

Hurtle (aged nine), *Dezma* (aged seven) and *Loril* (aged four)—All three showed marked and typical changes of equal degree, in the skull, pelvis, spine and long bones (Fig. 12). Sclerosis of the long bones was greatest in the middle and uppermost thirds of the femora and least but diffuse in the arms.

Lucent (aged fourteen)—In this case mild changes were confined to the pelvis and upper parts of the femora.

Sonia (aged eleven), *Daisy* (aged one) and *Mother* (aged thirty-nine)—No abnormality was detected.

Father (aged forty-two)—There was mild but definite sclerosis of the skull base and diffuse sclerosis throughout the pelvis and femora giving a hazy overlay to a slightly thickened trabecular pattern.

FIG. 5
Vanilla—skull.

FIG. 6

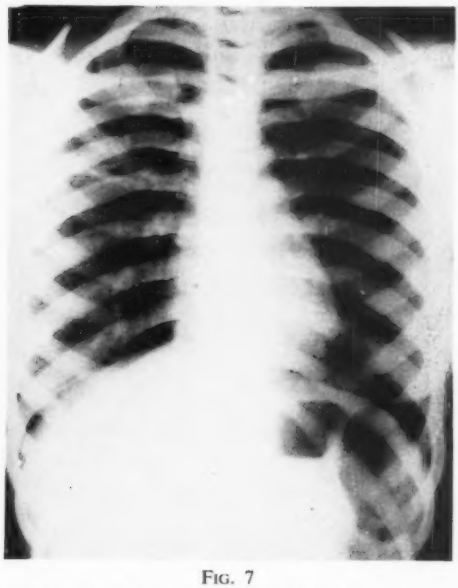

FIG. 7

Figure 6—Vanilla—lumbo-thoracic spine. Figure 7—Vanilla—chest showing generalised bone involvement.

Radiographic examination was repeated in April 1958 on eight members of the family. Seven of these showed no evidence of progression of the disease.

The mother was now thirty-two weeks pregnant. No abnormality was observed in her skeleton or that of the foetus.

Sonia now showed the development of early sclerosis with coarsening of the trabeculae of the pelvis and femora (Fig. 13).

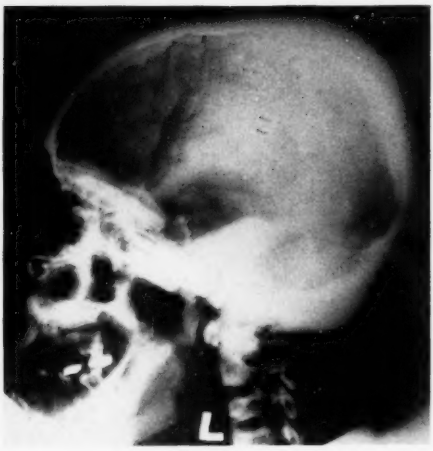

FIG. 8

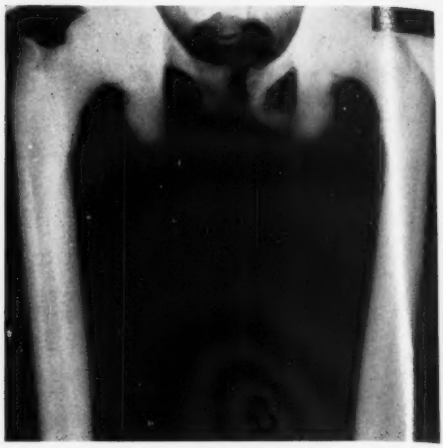

FIG. 9

Figure 8—Roy—skull. Figure 9—Roy—pelvis and femora. Extensive changes in a patient without symptoms.

DISCUSSION

The affected members of this family fit into the clinical picture of " benign " osteopetrosis, except that the degree of cranial nerve involvement is unusual. The tendency of the disease to reproduce itself in the same pattern of bones in the same family is emphasised by the onset of facial palsy in three siblings at the same age (Higinbotham and Alexander 1941). Involvement of the vault of the skull and facial bones is not usual but has been reported several times (Kretzmar and Roberts 1936, Falconer and Ryrie 1937, Higinbotham and Alexander 1941, Truswell 1958). Several of these cases were familial and some were associated with syndactyly.

The recent report by Welford (1959) of facial palsy due to osteopetrosis arising in five generations of a family at the age of about twelve indicates the possible importance of the disease as an unrecognised cause of familial facial palsy.

FIG. 10
Merval—skull.

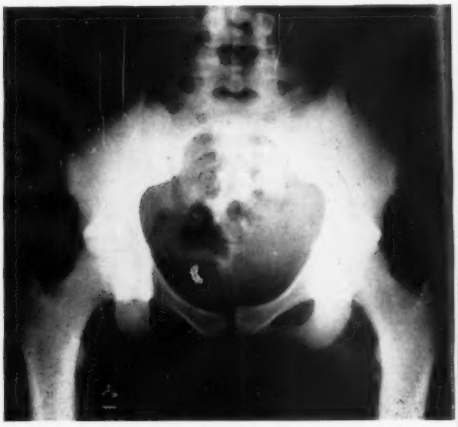

FIG. 11
Merval—pelvis.

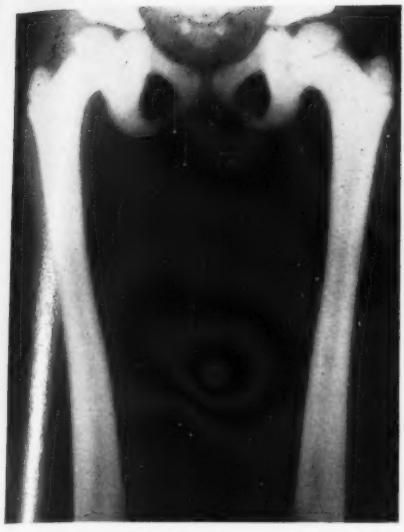

FIG. 12

FIG. 13

Figure 12—Dezma—femora. Figure 13—Sonia—femora. Early changes on second examination.

The extensive nature of the process in some siblings in the complete absence of symptoms is remarkable, as is the fact that none of the nine patients had sustained a fracture.

Another notable feature is the high level of serum alkaline phosphatase found in seven siblings, which is at variance with the few previous reports of this activity in osteopetrosis. Normal figures for alkaline phosphatase have been reported by Higinbotham and Alexander (1941), Thomson (1949), Seigman and Kilby (1950), and Hinkel and Beiler (1955).

The finding of the disease in a parent is not usual; there have, however, been reports of involvement of three generations (McPeak 1936, Bonomini 1954). We have found no previous record of the affection of eight siblings.

The radiological changes in this family show a predilection both for the base of the skull, which is intensely involved, and for the calvarium. Changes in the pelvis occurred in all cases in which the skull was involved, and the distribution in other bones is typical of the disease; the nature of the changes may also be considered typical, although they lack certain features which have been variously described in the " benign " condition by Pirie (1933), McPeak (1936), Fairbank (1948), Brailsford (1953) and Hinkel and Beiler (1955). These writers offer the following composite picture. The primary radiological change in the long bones is in the diaphysis. Sclerosis proceeds down the shaft; there is progressive narrowing of the medullary space, but in more severe cases the trabecular pattern and the differentiation of cortex and medulla are lost. Transverse lines of increased density may occur and there may be vertical " cracks " near the bone ends. Sclerotic bands may also occur in the phalanges and ribs. The clubbing deformity of the long bones which consistently occurs in the " malignant " osteopetrosis is not a feature, but there may be some increase in diameter of the shafts of the long bones. particularly in the distal half of the femur. The epiphyses show a dense nidus and the carpal and tarsal bones have sclerotic rings of a size apparently related to the age of greatest activity of the disease. Similarly the iliac bones may show uniform concentric shadows outlining their earlier margins. The vertebral bodies have a " sandwich " appearance due to

sclerosis at contiguous surfaces. The changes in the skull are primarily in the base, manifest in thickening of the clinoid processes and obliteration of air sinuses; sometimes there is involvement of the facial bones. Occlusion of foramina and homogeneous thickening of the vault are less usual.

In the cases we have described not only were the last two features conspicuous, but the change in all the less severely affected bones was a uniform increase in density with little loss of trabecular pattern and with thickening of the cortex at the expense of the medulla. Even in the mildest cases the transverse diaphysial band, sclerotic nidus and " sandwich " vertebra were absent.

The appearances, however, are like those reported by Seigman and Kilby (1950), Bonomini (1954) and Truswell (1958). Bonomini described a benign osteosclerotic condition in fourteen members of a family, which he considered to be a disease distinct from osteopetrosis. In our patients, however, there is a progressive gradation into typical advanced changes of Albers-Schönberg's disease.

Radiological differentiation between cortex and medulla is frequently lost (Caffey 1956), and total obliteration of the medullary space has been demonstrated histologically from the earliest studies (Goodall 1912, Nadolny 1924). However, depending on the severity of the disease and the penetration of the film, thickening of cortical bone at the expense of the medulla is a fundamental radiological feature of less advanced cases, and this has also had repeated histological confirmation (Assmann 1907, Clairmont and Schinz 1924). This does not imply that obliteration of the medulla advances progressively in the individual bone. On the contrary, it is widely believed that in this disease there is a heritable defect dating from foetal life; and it is frequently stated that this results in an abnormal persistence of calcified cartilage. The latter is manifestly an over-simplification, which does not for example explain the involvement of bones that develop in membrane. It also implies that at no stage is there a semblance of normal spongiosa.

In this respect, the onset of disease as observed in Sonia is of special interest—showing that in this case the spongiosa, supposedly abnormal from before birth, contained an apparently normal trabecular pattern up to the age of eleven years. To our knowledge the onset of these changes in a radiologically normal subject has never before been observed.

Pathology—The literature of osteopetrosis is made complex by the confusion of Teutonic terminology and the inherent vagueness of diagnostic criteria. Early work has been comprehensively reviewed by McCune and Bradley (1934), who clarified the concept that the basic defect lies in a faulty differentiation of the primitive osteogenetic mesenchyme, the excess of this foetal tissue interfering with endosteal and endochondral metabolism.

Pirie (1933) described abnormal calcified cartilage in the diaphysis, containing disorderly foci of ossification and small medullary spaces. Zawisch (1947), however, in a careful histological study offered evidence that the so-called cartilage in this disease may be plexiform bone of normal foetal type, and abnormal cortical bone may be mistaken for spongiosa. She described in one case persistence of primitive bone which normally undergoes complete resorption in three successive stages—apparently due to arrest at the onset of the second stage. The medullary space in this specimen remained of primitive size, surrounded by a wide zone of foetal plexiform bone with a narrow rim of normal lamellar bone laid down subperiosteally.

This therefore supports McCune and Bradley's concept of a mesenchymal defect, but is an elaboration of the theme that the abnormality is purely one of endochondral ossification. It would also explain the disease process in the membrane bones of the calvarium.

The aberration may be either in failure of resorption or in abnormal deposition; and Zawisch's evidence is that resorption, a function of vascular tissue, remains potentially active. It proceeds normally until blocked by the appearance of abnormal " second period "

mesenchyme. Resorption spaces may occur in abnormal sites in the cortex, and generalised resorption may occur in periodic bursts during the course of the disease (Henke and Lubarsch 1937), thus contributing to bizarre radiological appearances. The effect of such possible outbursts on the final picture is well illustrated by Fairbank (1948). These outbursts also offer a possible explanation of the occasional reports of hypercalcaemia and calcinosis in the disease (Schulze 1921, Flood 1929). The overall picture, however, is of a progressive disappearance of osteoclasts (Kneal and Sante 1951).

With regard to the blood picture, the differentiation of haemopoietic tissue from the primitive mesenchyme may possibly suffer interference at the same stage, leading to a general depression of blood-forming potential. Some differentiation to fibrous tissue occurs in the abnormal medullary spaces (Nadolny 1924, Kramer and Halpert 1939, Pines and Lederer 1947, Fairbank 1948). The surface area of these spaces is much reduced; and in addition, Zawisch believed that bone resorption itself offers a stimulus to myeloid activity which may be lacking in the disease.

All these variable factors adequately explain the variable degree of anaemia, which need not coincide with the extent of radiological " marbling "—for the latter is merely an index of calcification.

CONCLUSIONS

In the light of these findings it may be postulated that in " benign " cases of osteopetrosis inclusions of primitive foetal osteogenic tissue persist, but to such an extent that skeletal growth is normal and the formation of more mature trabeculae is only partly disrupted. Subsequently, the further stages of ossification may proceed tardily in these inclusions as in foetal life, but with modifications imposed by the advanced development of the patient—modifications which reveal themselves in excessive calcification, relative failure of resorption and a varying degree of interference with haemopoiesis. The final picture may be further influenced by remissions and exacerbations of resorption.

In the present limited state of knowledge it seems reasonable to include the members of the family we have described within the " spectrum " of Albers-Schönberg's disease. If the above postulates are applied to them, the uniform sclerosis of the affected bones might be interpreted as an indication of a steady maturation of primitive mesenchyme without outbursts of excessive resorption, and the raised serum phosphatase levels of the children as a retarded exhibition of the normal phosphatase activity of infancy.

SUMMARY

1. A type of bony sclerosis is described, occurring in nine members of a Jamaican family and resembling the more benign form of Albers-Schönberg's disease. The parents were consanguineous. Three of the patients developed facial palsy at the same age, and one had bilateral optic atrophy and proptosis.

2. Although radiological changes occurred of all grades of severity, certain features often described in this condition were lacking. In one child the onset of radiological changes was observed at the age of eleven years.

3. Serum studies showed increased alkaline phosphatase activity.

4. These features are discussed in the light of present-day knowledge and theory of the pathology of Albers-Schönberg's disease.

We wish to thank Professor E. K. Cruickshank and Dr J. C. Waterlow for permission to publish this report, and Dr J. Marryat for his cooperation and advice on the radiological investigations. We are also pleased to acknowledge the assistance of the staff of the Department of Pathology of the University College of the West Indies.

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FAMILIAL EPIPHYSIAL DYSPLASIA OF THE LOWER LIMBS

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The clinical entity called "dysplasia epiphysialis multiplex" was first described by Fairbank in 1947. It occurs during the period of growth, is due to a developmental error, and affects both sexes. The disease is characterised radiographically by delay in the appearance of the epiphysial nucleus, which is mottled and of irregular density. Premature closure of the affected epiphyses occurs. The epiphyses most commonly affected in Fairbank's twenty cases were those of the hips, shoulders and ankles. The condition is associated with dwarfism and stubby fingers.

A family is here described in which the changes characteristic of dysplasia epiphysialis multiplex were confined to the lower limbs. The family comprises six generations and consists of 114 members. The condition of five males and two females remains unknown, so that this paper concerns itself with 107 members of the family. Of these, twenty-two males and twenty-three females—forty-five in all—were affected by the disease; thirty-two males and thirty females—sixty-two in all—were unaffected.

Some of the affected members of the family have been under medical surveillance for periods of up to twenty-eight years. Eight of them (C2, D1, D6, D9, D10, D11, D12, D13) were reported by Druckmann (1937). Variations of the pattern of the disease were seen within the family. In some the disease produced severe deformity; in others the deformity was mild and caused only slight disability; and in yet others clinical and radiological examination did not show any abnormality. The hip was most commonly affected; the knee next. In no case was there involvement of the upper limbs. The spine was normal, except in a few cases presenting a minor irregularity of the vertebral end-plate. The disease produced particularly a marked shortening of the lower limbs in relation to the rest of the body.

GENEALOGY

At the time of this investigation the first two generations of the affected family were deceased, and information about their condition was obtained from their descendants. The family tree is shown in Figure 1; spouses are shown as normal.

The first known affected member (A) was born in Safad around 1830 of Caucasian Jewish stock. He was known to have had a severe limp. He had one son (B1) who had a marked waddling gait, and three daughters of whom two (B2 and B3) had a waddling gait; of the third daughter (B4) no details could be discovered.

B1 had only one son (C1), who was affected. C1 was married three times to three healthy unrelated women and propagated his deformity through all three wives to their children.

The B2 affected progeny were C2, C3, C4 and C5, three of whom transmitted their deformity to seven of their eleven children. Three children were unaffected and the fate of one child is unknown.

B3's progeny were C6, who is affected, and C7, who is unaffected and one other who is unknown. Of C6's six children four are affected and two are unaffected. C7's nine children are all unaffected.

Members of the third generation (C) were the first to be examined by us and were by this time fully grown adults. There were nine members, of whom six were affected (Fig. 2) and one was unaffected. No information about the other two could be obtained.

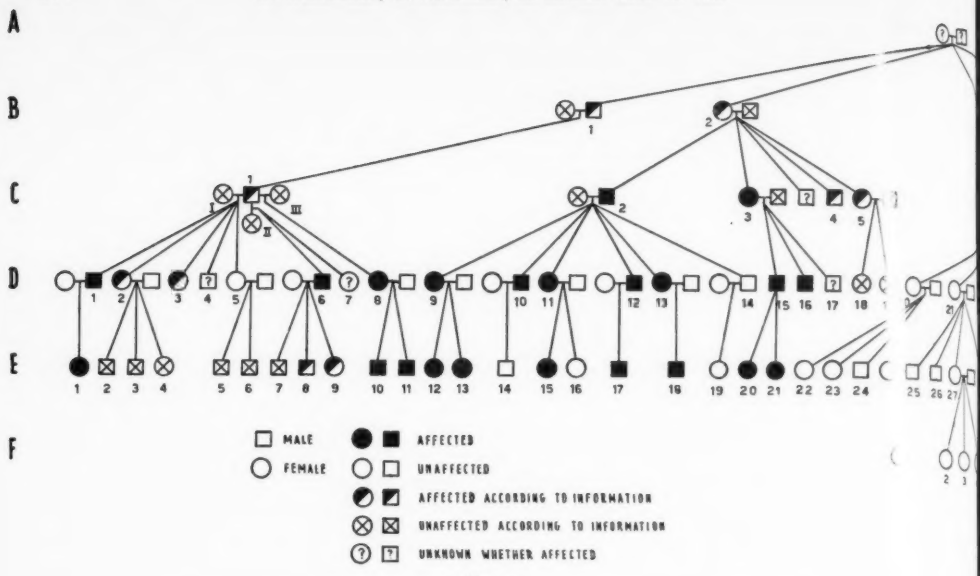


FIG. 1
Genealogy of the affected family: numerals indicate case numbers in this report.

The fourth generation (D) comprised thirty-four members, of whom sixteen were known to be affected—including D1 (Fig. 3), D8 (Fig. 4), D9 (Figs. 5 to 7), D10 (Figs. 8 to 10), D11 (Figs. 11 and 12), D12 (Figs. 13 to 16), D13 (Figs. 17 to 19), D16 (Figs. 20 to 22), D22 (Fig. 23) and D23 (Fig. 24)—and fifteen were unaffected. The condition of the remaining three is not known.

The fifth generation (E) comprised sixty-one members, twenty of whom were affected—including E1 (Figs. 25 to 28), E10 (Figs. 29 to 34), E11 (Figs. 35 and 36), E12 (Figs. 37 to 41), E15 (Figs. 42 and 43), E17 (Fig. 44), E18 (Figs. 45 and 46), E30 (Figs. 47 and 48), E32 (Figs. 49 and 50), E34 (Fig. 51) and E37 (Figs. 52 to 56)—and forty-one were unaffected.

The sixth generation (F) consisted of five members. No abnormalities were found in these at the time of examination.

It is significant that C7, her nine children, twenty-three grandchildren and one great-grandchild were all unaffected though her mother was known to be affected.

Genetically this family provides a typical example of a simple dominant inheritance with an extensive pedigree.

CLINICAL COURSE

The children appeared normal at birth and continued so for the first two or three years of life. Growth, weight and development were normal and there was at this stage no deformity or disability. At the age of four to six years medical advice was often sought because of waddling gait, genu varum or valgum and sometimes because of shortness of stature. In these young children pain was uncommon and in only a few instances did they complain of pain about the hip. In these cases examination revealed restriction of movement of the hip, particularly of abduction and medial rotation. Even though deformity was very evident at the knees and ankles pain did not occur and motion was not restricted. As the child developed, his short stature became more pronounced. The typical adult clinical picture was of striking disproportion in length between the normally developed trunk and upper limbs, and the markedly shortened lower limbs.

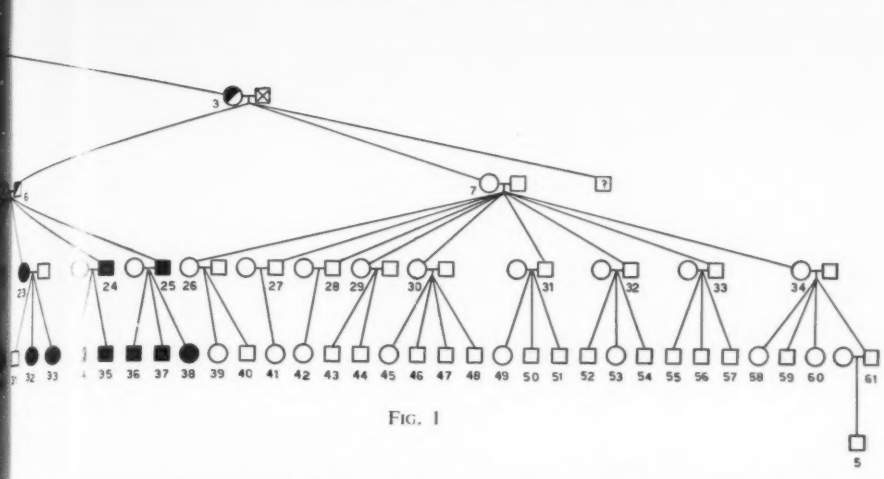


FIG. 1

There was usually a long latent period before clinical complaints appeared. Most of the affected adults adapted themselves to their deformity, married and produced families. They were all of normal intelligence and were occupied in manual or clerical work. The females were mostly engaged in housework. A typical waddling gait resulted, varying in severity with the degree of deformity. At the age of about thirty to forty the patient usually started to complain of fatigue on exertion and pains about the hip. The common complaints were typical of a degenerative arthritis of the hip from which he now suffered. Nevertheless, despite the severe deformity visible on radiographs most members of the family were not so severely crippled by the disease as to justify surgical intervention.

The height of a fully grown affected male did not exceed 60–61 inches (153–155 centimetres). The sitting height was 32–33 inches (82–84 centimetres), the length of the lower limbs about 27–28 inches (68–72 centimetres) and the arm span about 63–64 inches (160–163 centimetres). The average mean measurements for airmen of the United States Air Force are: height 69·1 inches (175·54 centimetres), sitting height 35·9 inches (91·28 centimetres), length of lower limbs 33·5 inches (85·15 centimetres) and arm span 70·8 inches (179·83 centimetres) (Hertzberg, Daniels and Churchill 1954). These measurements show that in the normal male the lower limb is about 2·4 inches shorter than the sitting height. In the family here presented which was of short stature, the length of the lower limb was about 5 inches shorter than the sitting height. In the normal male the height is about 1·6 inches (4 centimetres) shorter than the span, while in the family described the difference is about 3 inches (7 centimetres). These measurements emphasise the shortening of the lower limbs and the normal proportions of the rest of the body.

Further investigations were done in many of the affected patients. Blood sedimentation rate, blood counts, serum calcium, phosphorus, cholesterol, electrolytes and total proteins were normal. The possibility of familial hypothyroidism affecting the growing child during a certain phase of development was considered. However, studies of the uptake of radioactive iodine in twelve affected children gave results which were within normal limits.

RADIOLOGICAL FINDINGS

The radiological findings were characteristic and diagnostic. No abnormality was seen in radiographs taken during the first months of life; the earliest significant deviation from normal was delay in the appearance of the ossific centre of the femoral head. When this epiphysis first appeared between the ages of one and two years it was seen to be poorly developed.

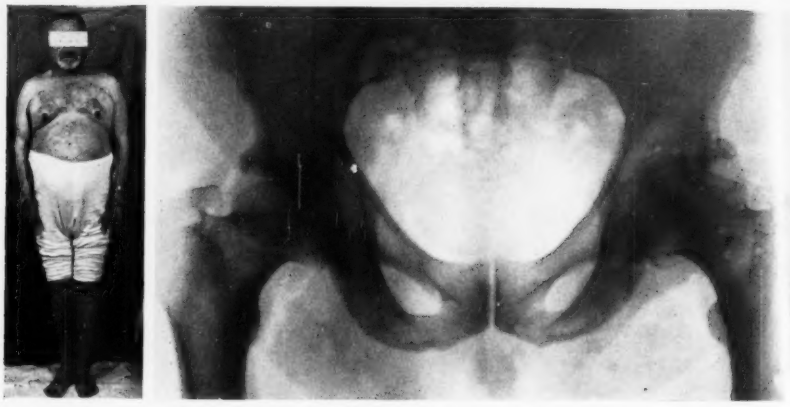


FIG. 2

Case C2—Sixty-seven-year-old man. First complained of pain about both hip joints twenty-eigl years ago. No increase of symptoms since then. The photograph shows relative shortening of lowe limbs, height 60 inches (153 centimetres), sitting height 30 inches (76 centimetres), arm span 5 inches (151 centimetres). The radiograph shows coxa vara with moderate mushrooming of th head, mild osteoarthritic changes.

FIG. 3

Case D1—Sixty-year-old man. Radiograph of hips. The head on the left side is small and severely deformed; on the right side it is hardly discernible. The neck is thickened and broadened, especially on the right side. The acetabula are deformed and irregular.

FIG. 4

Case D8—Thirty-eight-year-old married woman, height 57 inches (145 centimetres), no complaints. Was examined when she brought her elder son for examination. Radiograph of pelvis. Femoral heads and acetabula are markedly deformed and irregular.

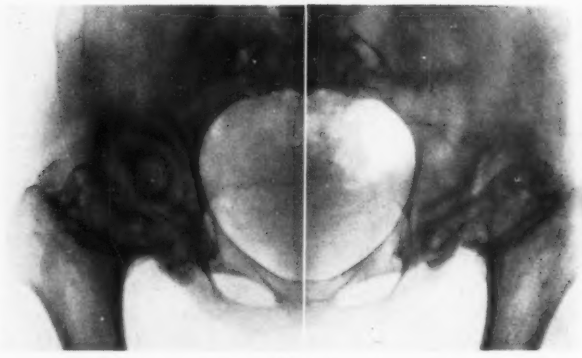


FIG. 4

FIG. 5

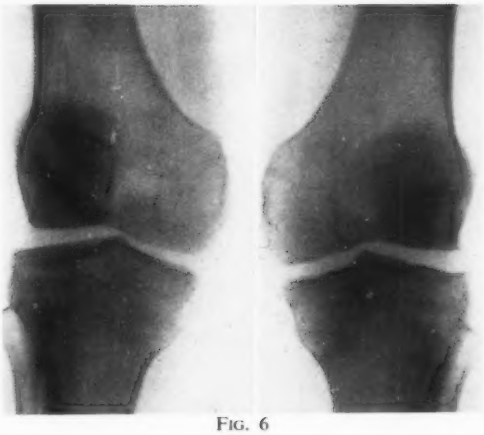


FIG. 6

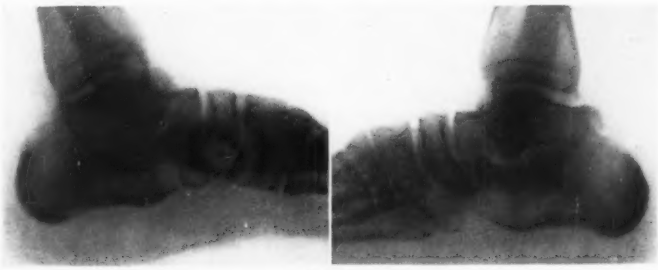


FIG. 7

Case D9—Daughter of C2. First examined at the age of fourteen because of waddling gait, when epiphysial plates of the femoral heads were seen to be closed. At present under treatment for severe pain in both hips. Figure 5—Radiograph of pelvis at the age of thirty-eight. Hatchet-shaped proximal ends of both femora, with coxa vara and mushrooming of the femoral heads. Subluxation with flattening of the acetabula. Figure 6—Radiograph of knees. The normal convexity of the femoral condyles is absent; the condyles are flattened and tend to be rectangular; the tibial condyles are flattened. The distal end of the femur is much wider than the shaft especially medially. Figure 7—Radiograph of ankle joints. Flattening of the tibial surface of the talus.

FIG. 8

FIG. 9

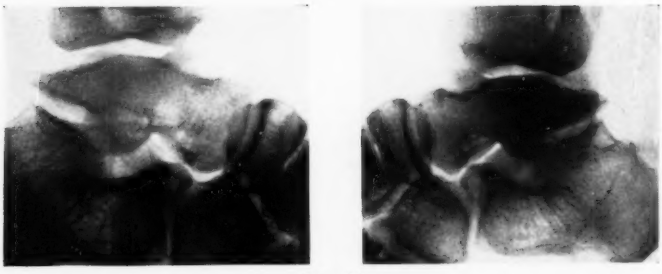


FIG. 10

Case D10—Son of C2. Came for advice because of waddling gait and short stature. Figure 8—Radiograph of pelvis at the age of sixteen years. Coxa vara with shortening of the neck on both sides, failure of bony modelling of the neck. Fragmentation of the head of the femur on the right side and of both greater trochanteric epiphyses. Irregularity of the acetabular margin. Figure 9—Radiograph of pelvis at the age of thirty-five years. The upper region of the femur is hatchet-shaped, with the irregular-shaped head well below the level of the trochanter. Deformity of both acetabula. Well defined bony fragments about the joints, probably remnants of the fragmentation of the greater trochanter. Figure 10—Radiographs of ankles at the age of thirty-five. Marked deformity, irregularity and flattening of the upper surface of the talus.

FIG. 11

FIG. 12

Case D11—Daughter of C2. First examined at the age of ten because of waddling gait. At the age of thirty-three she complained of severe pain about both hips. Figure 11—Radiograph of pelvis at the age of ten. The femoral capital epiphyses are small, flattened and sited over only a small region of the broad neck. The greater trochanteric epiphyses are overdeveloped. Figure 12—Radiograph of pelvis at the age of thirty-three. The femoral head is relatively well shaped, though deformed, but the acetabula are shallow.

irregular in shape and density and mottled in appearance. When weight bearing began the epiphysis became fragmented and the femoral head flattened. There was usually delay in appearance of the trochanteric epiphyses, so it seems that the whole epiphysis at the proximal end of the femur was affected. Later on, the femoral neck became plump and shortened. Even though the density of the epiphyses became normal the femoral head remained deformed and flattened. The epiphysial plates of the femoral head and of the trochanter were usually already closed by the age of fourteen to fifteen years. The femoral head was often severely deformed, and the neck was shortened and broadened and showed pronounced varus deformity. The greater trochanter appeared overdeveloped. There was mushrooming of the head so that the proximal femur often appeared hatchet-shaped. Coxa magna deformity with secondary subluxation of the hip commonly occurred. Shallowness of the acetabulum was considered to be secondary to the deformity of the femoral head.

FIG. 13

FIG. 14

FIG. 15

FIG. 16

Case D12—Son of C2. At the age of seven a marked waddling gait and genu varum were noticed. Bilateral tibial osteotomies were performed at the age of fourteen and gave good correction. Recently complained of pain on exertion in both hip joints. Figure 13—Patient at age of thirty-two. Showing marked disproportion between upper and lower limbs, height 60 inches (153 centimetres), sitting height 31 inches (79 centimetres), arm span 63 inches (160 centimetres). Satisfactory correction of bilateral genu varum. Figure 14—Radiograph of pelvis at the age of seven. Fragmentation of both femoral capital epiphyses. The joint space is widened, the neck is short and broadened. The greater trochanteric epiphyses have not appeared yet. Figure 15—Radiograph of knees at the age of fourteen. Genu varum due to deformity of the epiphysial cartilaginous plate of the tibia. The upper tibial epiphysis does not cap the metaphysis. Figure 16—Radiograph of pelvis at the age of thirty. The femoral head is mushroomed; the neck is shortened and broadened. Coxa magna with a very shallow acetabulum; the head is too big to fit into the acetabulum.

FIG. 17

FIG. 18

FIG. 19

Case D13—Daughter of C2. Was examined together with her father, her brothers and sisters because of waddling gait and shortness of stature. Figure 17—Patient at the age of twenty-nine. Showing relative shortening of lower limbs, height 57·5 inches (146 centimetres), sitting height 31·5 inches (80·5 centimetres), arm span 57·5 inches (146 centimetres). Slight genu valgum. Figure 18—Radiograph of pelvis at the age of five years. Bilateral coxa vara, fragmentation of the head of the femur, widening of the joint space. Very small, poorly formed greater trochanteric epiphyses. The modelling of the neck is defective. Figure 19—Radiograph of pelvis at the age of twenty-eight. Mushrooming of the head of the femur bilaterally, with shortening of the neck. Overdeveloped greater trochanter in comparison with the head. The joint space is well preserved.

Changes appeared also in other joints of the lower limb. At the knee there was affection of both lower femoral and upper tibial epiphyses. In some the condyles were altered in shape, and separate centres of ossification at the back of the femoral condyles were not uncommon. Genu valgum or genu varum was often present. The distal tibial epiphyses were often irregular in outline and deformed, and some obliquity of the ankle joint was common because the lower tibial epiphysis was much thicker medially than laterally. Several cases showed flattening and irregularity of the talus with compression of its upper surface. In other cases sclerosis and deformity of the navicular bone were observed.

The shafts of the long bones of the lower limbs, while not deformed or thickened, were shorter than normal.

TREATMENT

Several attempts to correct severe deformities were made. Femoral supracondylar or tibial osteotomies were performed on some patients before the age of six. In these cases the immediate post-operative correction was satisfactory, but as the child continued to grow the deformity reappeared and called for further operation later. When osteotomies were performed at about the age of fourteen years, close to the end of the period of growth, the results were more satisfactory and permanent.

FIG. 20

FIG. 21

FIG. 22

Case D16—Son of C3. Thirty-one years old, with no complaints. Marked waddling gait. Figure 20—Showing marked disproportion between the upper and lower limbs, the tips of the fingers nearly reaching the patellae, height 59·5 inches (151 centimetres). Normally developed trunk and skull. Figure 21—Radiograph of pelvis. The proximal femoral area is markedly hatchet-shaped. The femoral head is so deformed as to be no longer distinguishable. The acetabula are flattened. Figure 22—Radiograph of knees. The femoral condyles are flattened and rectangular. The tibial condyles show an inverted V-shape. The distal ends of the femora are markedly broadened.

DISCUSSION

Since Fairbank's (1935) original report, there have been numerous reports of this disease, some with significant variations from his original description. The familial aspects of this condition were not emphasised by Fairbank, and he even stated that the disease was not as a rule inherited or familial, although several of his own patients were members of the same family. Later reports have, however, emphasised the frequent familial nature of this disease.

Druckmann (1937) considered the affection in eight members of this family to be related to osteochondritis juvenilis. He took the view that osteochondritis of the hip (Legg-Calvé-Perthes), osteochondritis dissecans, malacia of the lunate bone (Kienböck), of the tarsal navicular (Köhler) and of the metatarsus, the affection of the tibial tuberosity (Osgood-Schlatter) and osteochondritis of the spine were identical in their etiology.

Barrington-Ward (1912) described affection of a brother and a sister; Gardiner-Hill (1937) two sisters; Resnick (1943) a mother and her twin boys; Waugh (1952) three sisters; and Christensen, Ru Kan Lin and Berghout (1955) a mother and her two daughters. Maudsley

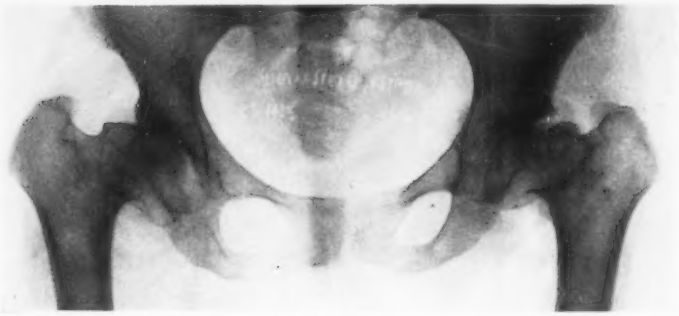


FIG. 23

Case D22—Woman, thirty-nine years old. Radiograph of pelvis. Hatchet-shaped proximal ends of both femora, with coxa vara and mushrooming of the head of the femur. Partial subluxation. Early degenerative changes.

FIG. 24

Case D23—Woman, thirty-eight years old. Radiograph of hips. Hatchet-shaped proximal ends of both femora, with coxa vara and mushrooming of the femoral heads.

(1955) reported fourteen cases in three families, differing in some aspects from Fairbank's original description. Shephard (1956) reported three cases of multiple epiphysial dysplasia in three generations of one family; and Litchman and Chirls (1958) described seven cases, of which four belonged to one family and two to another. Jackson, Hanelin and Albright (1954) described several examples of this syndrome including four in one family, and stressed the simple genetic inheritance, with high penetrance. They discussed the differential diagnosis between conditions which show epiphysial fragmentation and irregularity.

The family here reported differed in several respects from Fairbank's original description. The condition was familial and hereditary. The vertebral column was unaffected and the upper limbs including the fingers were normal. In early life the disease could only be detected radiologically as usually there is no overt sign of its presence. The infants here reported were almost all examined at our request. Skeletal deformity became apparent later. The severity of the condition varied even within the same branch of the family, several members being unaffected. The children were brought for advice at the age of about five or six years because of deformities of the lower limbs and waddling gait. In their late thirties most patients began to complain of pain from secondary osteoarthritic changes in the hips.

FIG. 25

FIG. 26

FIG. 27

FIG. 28

Case E1—Daughter of D1. Aged seventeen. Brought for examination because of short stature and waddling gait. Figure 25—Radiograph of pelvis at the age of two years. The femoral capital epiphysis is minute, especially on the right side; there is broadening, irregularity and fragmentation of the neck. Figure 26—Radiograph of pelvis at age of four. The vertical defect in the neck is typical of congenital coxa vara. Figure 27—Radiograph of pelvis at the age of six. The epiphyses of the greater trochanters are still absent. Figure 28—Radiograph of pelvis at the age of seventeen. Flattening, irregularity and subluxation of the femoral heads, especially on the right side. Well developed greater trochanters.

FIG. 29

FIG. 30

FIG. 31

FIG. 32

Case E10—Son of D8. Figure 29—Radiograph of pelvis at the age of three years. No femoral capital epiphysis visible. Broadened, flat, shortened neck. Wide joint space. Figure 30—Radiograph of pelvis at the age of six. The femoral head is still not evident, the neck is broad, irregular and shortened. No greater trochanteric epiphyses visible. Irregular acetabular margins. Figure 31—Photograph at the age of ten years: severe genu varum and bowing of legs. Tips of fingers reach almost to the patellae. His height, 44 inches (112 centimetres) was little more than that of his brother aged five (Fig. 36). Figure 32—Radiograph of pelvis at the age of ten. Small irregular femoral capital epiphysis, especially on the right side. A broad, wide, short neck which is beaked at its infero-medial corner. No evidence of greater trochanteric epiphyses.

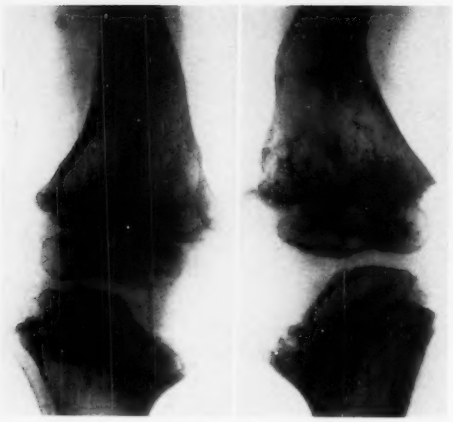


FIG. 33

FIG. 34

Case E10.¶ Figure 33—Radiograph of knees at the age of ten (after bilateral supracondy osteotomy of the femur for correction of genu varum). There is irregular sclerosis of the metaphys regions of the femur and tibia. The medial margins of the femoral and tibial metaphyses proj inwards over the epiphyses. Dislocation of the upper tibio-fibular joint. Figure 34—Radiograph ankle at the age of ten. Sclerosis and irregularity of the metaphysial region of the tibia and fibu The epiphysis of the tibia is irregular, as is the upper surface of the talus. The medial corner of t tibial metaphysis projects over the edge of the epiphysis.

FIG. 35

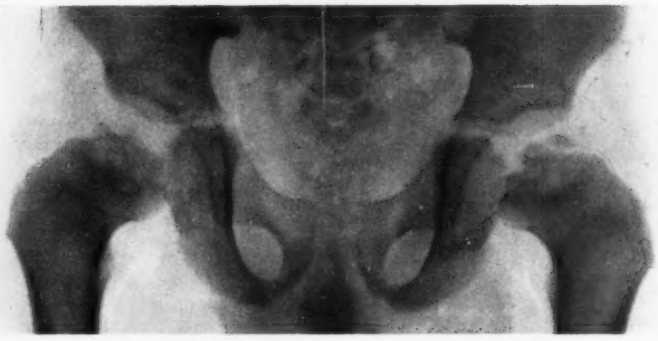


FIG. 36

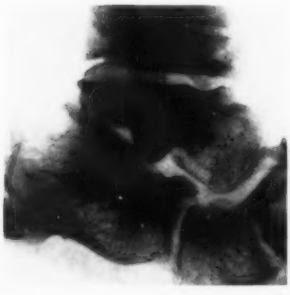
Case E11. Figure 35—Radiograph of pelvis at the age of one year. Small flattened, fragmented femoral capital epiphysis. Widening, fragmentation and inverted V-shaped indentation of the neck. Figure 36—Clinical photograph and radiograph of pelvis at the age of five. Femoral head fragmented and irregular, neck shortened and broadened. No epiphyses of the greater trochanters visible.

FIG. 37

FIG. 38

FIG. 39

FIG. 40



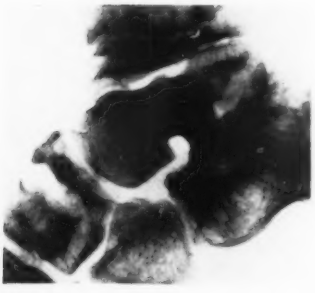


FIG. 41

Cases E12 and E13—Daughters of D10. Figure 37—E12 (*left*) is shown at the age of ten years and E13 at eight years. Figure 38—Case E12. Radiograph of pelvis at the age of two years. The capital femoral epiphyses have not yet appeared; the neck is wide and broad. Figure 39—Radiograph of left hip at the age of six years. Marked fragmentation of the small compressed capital femoral epiphysis; the neck is broad; the greater trochanteric epiphysis has not yet appeared. A large portion of the broad and short neck appears intra-articular and the metaphysis is barely capped by the epiphysis. Figure 40—Radiograph of left hip at the age of ten years. The process visible in Figure 39 has continued. The broad flattened neck is capped by a tiny epiphysis; the greater trochanteric epiphysis is absent. Figure 41—Radiograph of ankles at the age of ten years. Flattening and irregularity of the upper surface of the talus. Increased density and compression of the navicular bone.

FIG. 42

FIG. 43

Case E15—Daughter of D11. No symptoms. Was brought for examination at the age of three years. Under observation since then. Figure 42—Radiograph of pelvis at the age of three. The neck is very broad and notched in the middle, the acetabula are flat. Figure 43—Radiograph of pelvis at the age of eight. Fragmentation of the head on the left side; on the right side the capital femoral epiphysis is relatively small; the neck is broad and short on both sides. The greater trochanteric epiphyses have not appeared yet.

FIG. 44

Case E17—Son of D12. Radiograph of pelvis at the age of eight months. Delay in the appearance of the right capital femoral epiphysis; both femoral necks are broadened.

FIG. 45

FIG. 46

FIGS. 45 AND 46

Case E18—Son of D13. Figure 45—Radiograph of pelvis at the age of twenty-two months. The capital femoral epiphyses are still not visible; the necks are short and broad with irregular borders; and the coxa vara formation is more pronounced. Figure 46—Radiograph of lower limbs at twenty-two months. Marked bowing of both tibiae.

FIG. 47

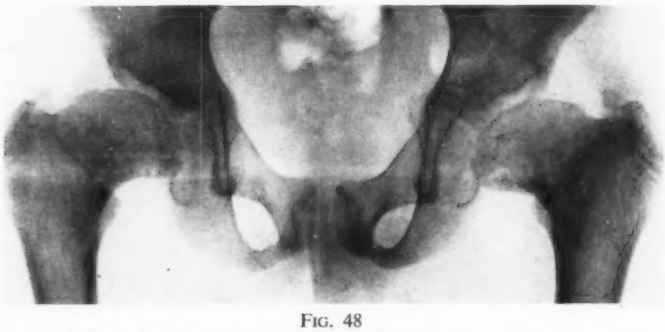


FIG. 48

Case E30—Daughter of D22. Figure 47—Radiograph of pelvis at the age of eight years. Irregular mottled and fragmented capital femoral epiphyses. Short and broad neck. The greater trochanteric epiphyses have not appeared yet. Coxa vara starting to develop. Figure 48—Radiograph of pelvis at the age of fourteen. Fusion of the femoral capital epiphysial plate, marked coxa vara. The epiphyses of the greater trochanters are clearly visible, fragmentation of the greater trochanters.

FIG. 49

FIG. 50

Case E32—Daughter of D23. Figure 49—Radiograph of pelvis at the age of five years. Fragmentation and mottling of the proximal femoral epiphyses and of the metaphysial region of the neck. The joint space is markedly widened. The greater trochanteric epiphysis has not yet appeared. Figure 50—Radiograph of pelvis at the age of twelve. The deformed femoral head has a mottled irregular appearance, and its superior surface is flattened. The femoral capital epiphysis appears to have fused. The trochanteric epiphysis is small and fragmented. There is a marked coxa vara.

FIG. 51

Case E34—Radiograph of pelvis at the age of two. Fragmentation of the femoral capital epiphyses. Broadening of the neck.

FIG. 52

FIG. 53

FIG. 54

FIG. 55

FIG. 56

Case E37—Son of D25. Figure 52—Photograph at the age of seven years. Severe genu varum, short stature, normal upper limbs. Figure 53—Radiograph of pelvis at the age of three years. The upper femoral epiphysis is still absent but there is fragmentation of the broadened neck. Figure 54—Radiograph of pelvis at the age of nine years. There is only a trace of a minute femoral capital epiphysis. Fragmentation of the neck of the femur persisting. Fragmentation of the trochanteric epiphysial region. Coxa vara. Figure 55—Radiograph of knees at the age of three years. The femoral epiphyses are flattened at their medial border, and the medial metaphysial region of the femur is irregular, mottled and protruding. The medial metaphysial region of the tibia is similarly fragmented, mottled and protruding. Figure 56—Radiograph of knees at the age of nine years. There is irregular sclerosis of the metaphysial region of the femur and tibia. Bony projections on the medial metaphysial side of each bone. Dislocation of the upper tibio-fibular joint.

SUMMARY

1. A family of six generations, consisting of 114 members affected by epiphysial dysplasia of the lower extremities, is described.
2. Twenty-two males and twenty-three females were affected, while thirty-two males and thirty females were unaffected. Seven members of the family could not be traced.
3. Variations from Fairbank's description of dysplasia epiphysialis multiplex are discussed. In the family here reported the lower limbs only were affected and the severity of the disease was very variable.
4. Long term follow-up studies are presented.

Our thanks are due to Professor A. Druckmann for permission to include cases C2, D1, D6, D9, D10, D11, D12 and D13 in this paper, and to Dr E. Margolis for his advice on the genetic aspect.

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A MODIFIED LAMBRINUDI OPERATION FOR DROP FOOT *

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The Lambrinudi arthrodesis for drop foot is a popular operation not only because it yields good results but also because fusion occurs more easily than in other methods.

The Lambrinudi operation is usually indicated in the correction of talipes equinus or equinovarus. The chief features of the operation are: excision of a wedge of bone from the talus and calcaneum, including the subtalar joint; excision of the calcaneo-cuboid joint and the lower part of the navicular bone; and the insertion of the remainder of the talus between the navicular and the cuboid bones (Fig. 1).

Performed in this manner, the operation gives excellent results in patients with moderately severe club foot, whether congenital or paralytic. However, in the very severe deformities the correction that can be obtained is not sufficient. The main obstacle to increasing the correction is that both the angle and length of the wedge of bone that can be taken from the talus and calcaneum are limited and cannot be extended sufficiently.

Any modification of the operation designed to give sufficient correction to the severest club foot must increase the size of the wedge of bone taken from the talus and calcaneum, but must not depart from the principles of the Lambrinudi arthrodesis which gives such favourable conditions for sound fusion. In order to achieve this, the operation has been modified. The wedge of bone from the talus and calcaneum is removed, as is the whole of the navicular bone and the top part of the cuboid bone, thus extending the angle and length of the wedge (Fig. 2). The calcaneo-cuboid joint is resected widely. The lower halves of the cuneiform bones are excised as a whole so as to fit the remaining beak of the talus.

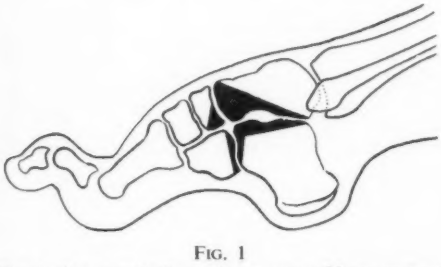

FIG. 1

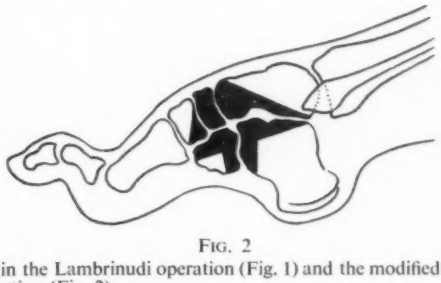

FIG. 2

The shaded areas indicate the amount of bone removed in the Lambrinudi operation (Fig. 1) and the modified Lambrinudi operation (Fig. 2).

This procedure allows the severest club foot to be corrected to the required amount to give a plantigrade foot; if there is shortening of the limb as a whole some equinus may be left to compensate for this.

TECHNIQUE OF OPERATION

The operation is performed through a curved lateral (or Kocher) approach, and the peroneal tendons are cut. The talo-navicular, subtalar and calcaneo-cuboid joints are opened, and the navicular bone is excised (Fig. 3).

* Based on a paper read at the Annual Meeting of the Hungarian Orthopaedic Association, Budapest, September 1956.

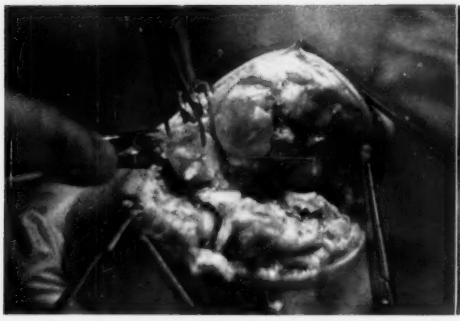

FIG. 3

FIG. 4

FIG. 5

FIGS. 3 TO 5

The modified Lambrinudi operation. Figure 3—The navicular bone is being removed. Figure 4—The lower parts of the cuneiform bones are being gouged away. Figure 5—The wound after apposition of the bones and before repairing the peroneal tendons.

The calcaneo-cuboid joint is excised next, and then a wedge of bone is removed which includes the lower surface of the talus, the upper surface of the calcaneum and the upper part of the cuboid bone. The lower parts of the cuneiform bones are removed with a gouge (Fig. 4) to fit over the beak of the talus. The raw bone surfaces are apposed (Fig. 5), the peroneal tendons are sutured and the wound is closed.

The foot is immobilised for four months in a plaster, in which the patient is allowed to walk after three weeks.

COMPLICATIONS

The patients with congenital talipes were particularly liable to skin and soft-tissue necrosis after the operation, in two of whom it was so severe that the final result was poor. It was thought that tightness of the skin and contracture of the subcutaneous tissues was the cause of this, and to prevent a recurrence of this complication plantar fasciotomy or a Steindler operation was performed when the deformity of the foot warranted it. After these procedures the foot was immobilised in plaster for five weeks with as much correction as possible. No further vascular complications have been seen after the combination of this preliminary soft-tissue operation with the modified Lambrinudi arthrodesis.

RESULTS

From 1952 to 1959 forty-four modified Lambrinudi arthrodeses have been performed, eighteen for congenital and twenty-six for paralytic talipes equinus or equinovarus.

The results have been excellent in forty-two of the forty-four patients, for whom no other method could have given such good correction (Figs. 6 to 9). This procedure is now used routinely.

FIG. 6

FIG. 7

Figure 6—Radiograph of the foot of a man aged twenty with an equinocavus deformity. Previous lengthening of the calcaneal tendon had resulted again in the severe deformity. Figure 7—The same foot one year after a modified Lambrinudi arthrodesis. Good correction and sound union have been achieved. The patient is able to walk long distances in ordinary shoes without any difficulty.

FIG. 8

FIG. 9

The right foot of a nine-years-old boy with talipes equinovarus is shown before operation in Figure 8, and after a modified Lambrinudi arthrodesis in Figure 9. Good correction and a satisfactory position have been obtained.

DISCUSSION

It is not necessary to lengthen the calcaneal tendon, even when the equinus deformity is very great. This is an important consideration in the paralytic patient because whatever power there is in the calf muscles is left unimpaired with consequent better function of the ankle.

A further advantage of this modified procedure is that both the adduction and cavus components of the deformity are easily corrected, because the anterior tarsal joints are included in the operation.

SUMMARY

A modified Lambrinudi arthrodesis is described which has given excellent results in forty-two out of the forty-four operations for the severest types of club foot.

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PRIMARY SUBTALAR ARTHRODESIS IN THE TREATMENT OF SEVERE FRACTURES OF THE CALCANEUM

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Fractures of the calcaneum [os calcis, calcaneus] in which the posterior articular facet is depressed, comminuted, or both, notoriously lead to poor function. So poor is this in fact that Bankart (1942) wrote: " The results of treatment of crush fractures of the os calcis are ro en... It would seem that the best result that can be expected from a fracture of the os calcis in olving the sub-astragaloid joint is a completely stiff but painless foot of a good shape, and wi h free movement of the ankle joint."

Different methods have been attempted and described in the search for better results. Open and closed methods are described, and the results have been so unsatisfactory that many fractures are deliberately left unreduced, and early movements begun.

Closed methods of treatment for this crush fracture depend upon the use of Steinmann or similar pins. Böhler (1931) employed single pin skeletal traction; Harris (1946) used three pins with the traction radiating from the foot to a circular support around it. Westhues (1934) attacked the fractured fragment directly, attempting elevation on the end of a pin. There are many other methods combining various procedures.

Open reduction was reported by Bell (1882) and Morestin (1902) but it appears to have found little favour until recent years. Lenormant, Wilmoth and Lecoeur (1929) described reduction of the fragments under direct vision, and Whittaker (1947) described a similar reduction but advised the use of metallic internal fixation for the unstable fragment. Palmer (1948) described open reduction in some detail. Being dissatisfied with the results of conservative treatment, he performed three subtalar arthrodeses at an early stage. These had all been moderately successful, but he was disturbed by the amount of soft-tissue stripping required in the lateral approach that he had used, and was concerned for the blood supply to the bone. He also found that the feet were left in a varus position after an adequate removal of cartilage. From these operations he found that the depressed fragment was sharply outlined, firm and stable: by applying traction to the heel he reduced what he called the forward deformity of the main fragment, and then elevated the depressed fragment of the posterior articular facet. This left a gap which he packed with iliac bone. He commented on the uselessness of simple traction in this particular deformity, because it could be seen at operation that the intact part of the facet of the calcaneum was pulled away from the talus, but nothing was done to correct the impaction of the smaller fragment.

In 1952 Essex-Lopresti described reduction by means of the Gissane spike under direct vision. He, too, appreciated that after disimpacting the fragment a considerable cavity was left, but he found that if the fragment was maintained in position by incorporating the elevating spike in plaster the cavity filled with new bone; a graft was not required in fresh fractures. There was developing meanwhile a more radical school of surgeons who believed that the joint was damaged past hope of useful function, and advocated arthrodesis. Van Stockum (1912) presented some successful subtalar arthrodeses in the treatment of this fracture. His paper attracted little attention despite the tremendous disability accompanying this injury, which was estimated in the 1920's as 2 per cent of all fractures, and of which Cotton and Henderson (1916) had said that any workman who sustained it was " done " so far as heavy work was concerned. An excellent report of the operative treatment was made in 1927 by Wilson, who described subtalar arthrodesis through a lateral approach which permitted eighteen of twenty patients to return to their old jobs in seven months. In the remaining

two cases one patient had Buerger's disease, and in the other the operation had failed because of a technical error. Wilson again reported on this procedure in 1933, having followed thirty-three out of forty patients. Twenty-four had good results and six fair. He made the comment which is no less true to-day than it was in 1933: " This is an operation only for the surgeon experienced in this region."

Cotton (1935) wrote that the lack of success in conservative treatment, when fusion had been confined to the subtalar joint, was due to depression of the sustentaculum tali. Although believing in and recommending arthrodesis after a preliminary five weeks of traction, he thought that a triple arthrodesis was essential. He restated this belief in 1943 when discussing Gallie's paper, and stated that the reciprocal function of the posterior tarsal and mid-tarsal joints demanded that, when one had been fused, the other must also be fused. Gallie (1943) described a posterior approach to the joint and gave, among other indications for fusion, the presence of articular irregularity. In the same year, and for much the same reasons, Armstrong (1943) described the use of a cortical bone graft passed from the superior surface of the neck of the talus down and back through the calcaneum. This seems to be mechanically unsound because the graft is passed along the axis of movement instead of at right angles to it (Hall 1955). Dick (1953) wrote strongly in favour of early arthrodesis to save the patient time and needless pain. He reported ten patients who had all returned to work in less than seven months after the injury. After these reports of excellent results obtained from an early arthrodesis as a primary treatment of the severe fracture, Lindsay and Dewar's paper (1958) came as a complete reversal of the previous statistics. After examining a series of 144 fractured heels they concluded that of the group treated by early arthrodesis only 60 per cent had a good clinical result compared with 76 per cent of a similar group treated conservatively.

Severe fractures of the calcaneum, with joint comminution and depression, have for some years been treated in St Joseph's Hospital by early arthrodesis limited to the subtalar joint. In this paper the results of this treatment will be discussed.

TREATMENT

After the initial radiographs an immediate decision is made on the treatment necessary. Operation is performed on all joints showing gross depression or comminution; usually within a week of the injury. In some cases operation is delayed because of skin blisters, and other patients may be admitted to hospital after a period of rest and elevation elsewhere. The following is an account of the procedure at present employed. Two teams of surgeons work using separate instruments and nurses. The patient is prone. One surgeon takes the bone graft from the posterior superior iliac spine, while the other works on the foot. One Steinmann pin is inserted into the posterior inferior part of the calcaneum and another into the shaft of the lower tibia. With the Roger Anderson distraction apparatus it is possible to separate these pins and open the damaged joint. A procedure similar to this but for definitive treatment was described by Shaar and Kreuz (1943). The method described by Gallie is then followed with some minor alterations. The same posterior approach, lateral to the tendo calcaneus, is used. Distraction of the joint by the Roger Anderson apparatus helps the exposure and increases the working space. It also permits, facilitates and maintains accurate correction of any varus or valgus deformity. Some attempt at correction of the articular surfaces is made in order to approximate the greatest surface area, but this is not a meticulous restoration as in Palmer's operation. Articular cartilage is gouged away from the posterior joint surfaces and a trough one inch deep and half an inch wide is cut across the two bones. This trough is packed with cortical strips of iliac bone, and a considerable quantity of cancellous bone is packed in and around it. While distraction is maintained the lateral expansion is corrected manually. The distraction is then released, the wound is closed, and a below-knee plaster incorporating the pins is applied. The pins are left in place in order to maintain the correction of the upward displacement of the posterior end of the calcaneum, and to prevent varus or

valgus deformity. The patient is allowed up gradually from the seventh day after operation; the pins are removed and the plaster is changed after four weeks. A walking plaster is applied at the end of the second month, and if the patient is walking well and the radiographs are satisfactory immobilisation is discontinued at the end of the third month: active exercises and full weight bearing are then encouraged.

MATERIAL

Periods of observation vary from twenty-one months to ten years. The patients have been under the care of four members of the staff of St Joseph's Hospital. During this period forty-four patients with severe crush fractures of the calcaneum have been treated, representing fifty primary arthrodeses because some patients had bilateral fractures. Four patients were women. Of these forty-four patients two have died, thirteen were not traced, and twenty-nine were examined by the authors. Three of these twenty-nine patients had a bilateral arthrodesis. Twenty-seven patients were covered by Workmen's Compensation Board Insurance. Many others belonged to insurance schemes that paid such varying parts of their lost wages that it was not possible to assess the patients on this basis. It is considered that this must be so with many reported series of fractures and that a distorted picture is given when too definite a distinction is made between insured and non-insured patients.

RESULTS

Results are not easily assessed on a basis comparable with other series. The patient's opinion is not unreservedly reliable: for example—" I am terribly grateful to the doctor who put the broken bones in my feet together. I can only walk one block." However, if he is a heavy labourer and he has returned to work without difficulty the operation must be regarded as successful, as it must be also in a man whose work is less strenuous but who has not given up any of his normal activities. Many patients find it hard to separate the activities which they had to give up on account of their fracture from those in which they were losing interest as age advanced.

Assessment—The classification of Maxfield and McDermott (1955) has been used so that some comparison may be made between the results of this procedure and of that described by Palmer. These categories are: excellent—no pain and no limitation; very good—no serious interference, but minor complaints; fair—activity restricted by pain; poor. Thus the patients with " excellent " results have returned to their full previous employment and perform a

TABLE I

RESULTS IN THIRTY-ONE CASES OF SUBTALAR ARTHRODESIS

Excellent — 5 (16·1 per cent)	Fair— 6 (19·3 per cent)
Very good—18 (58·0 per cent)	Poor—2 (6·6 per cent)

normal day's work. They have no limitation of their social lives, and no pain in the injured feet. Those with " very good " results have returned to their full previous employment, but have some ache or do not lead quite as active a social life as previously, but are without major restriction of their activities. There may be some criticism of the inclusion of patients in this group who have had to give up any activity, but to put a patient in a lesser category when he is capable of a full day's heavy work on his feet, often on irregular ground and without major complaint, would not give a true picture of the result. The group called " fair " includes

those patients who have modified their work, some who have to rest during it and others who have had to find a lighter occupation. It includes also those who have a major restriction of their social life, but who remain employed in their normal occupation. " Poor " is used for a group of unsatisfactory results to be described individually.

Of the thirty-two arthrodeses one has been excluded because of a later injury. The results are shown in Table I.

Return to work—Of the twenty-nine patients examined, twenty-five returned to their full previous employment. Details of the four who failed to do so are given below.

Case 1—A man aged thirty-five years, who had previously been employed in sheet metal work involving a good deal of ladder work, gave this up to drive a truck because " I wouldn't trust my feet." He had had an unsuccessful triple arthrodesis for congenital equino-varus deformity of the other foot, with gross residual varus, and had also an artificial eye. His decision to change his occupation is not surprising.

Case 2—A man aged twenty-three years had been employed as a labourer on the freight tracks at the time of his injury. The railway company would not re-employ him and he has since been trained as a spot welder.

Case 3—A man aged thirty-one years returned to his previous work as a labourer in a mattress factory. He gradually found himself unable to do this work, not because of pain in the heel but because of swelling and generalised pain in the leg. The cause was obscure. It may have been due to a deep thrombosis resulting from the accident or operation, but no connection could be established.

Case 4—A man aged forty years who was employed as a window cleaner. This was the most disastrous case of the series. The patient developed pin track infections in both the calcaneum and tibia, and eventually had a below-knee amputation.

Modification of work was found necessary in the following two patients.

Case 5—A man aged fifty-two years is employed as a painter in the same job he had before his injury. He had sustained bilateral fractures, but only one side was operated upon immediately. He now has to take frequent rests during the working day. He says the need for resting is caused by the foot on which operation was delayed and not the one that was operated upon immediately.

Case 6—A man who was employed as a lathe operator is the grateful patient who can walk one block. He sustained his fracture at the age of sixty-four and had returned to his previous work within four and a half months. Because of an ailing wife and a " tired " feeling he retired after six months. He later sustained an injury to the ankle on the same side and has, on that account, not been included in the statistics.

Time of return to full employment—Of the twenty-nine patients examined the time of return to work is not known by two of them. The amputee (Case 4) and the patient who had a subsequent injury (Case 6) are excluded.

The longest period off work was nineteen months, the shortest two months. The average time off full employment was 6·4 months from the time of injury.

Ache and pain—An exact distinction between these two complaints is not easily given briefly, but in most cases the patients had no doubt in separating them. It was found that about 25 per cent were completely free of either complaint, 50 per cent had some ache, and 25 per cent had some pain at times though not necessarily sufficient to interfere with their activities.

Tenderness—It was clearly established that the successful patient who had avoided complications was completely without tenderness. Lateral sub-malleolar tenderness was particularly sought, and was found in five cases. Two of these had a failure of bony ankylosis, two had had post-operative infections that had subsided, and the fifth had marked degenerative changes of the ankle joint. Many of the patients without this tenderness had a typical bony prominence beneath the lateral malleolus, which Lindsay and Dewar (1958) reported to have had no radiographic correlation with the complaint.

Function of tendo calcaneus—This was assessed principally on the patient's ability to rise up and hop on his toes. Without exception it was found that this was a satisfactory test in that

the patient either had no hesitation in its performance or was obviously unable to do it. The same patients who had lateral sub-malleolar pain had loss of tendo calcaneus function, whereas the other patients without tenderness had no loss of function. No correlation was found between the degree of correction of the elevation of the posterior end of the calcaneum and tendo calcaneus function.

Alteration of sensation—There has been a suggestion that pain after injury to the subtalar joint may be relieved by neurectomy (Nyakas and Kiss 1954, Sallick and Blum 1948). It has also been suggested that injury to the sural nerve during the exposure might result in less subsequent pain. In this group six patients had sural nerve injury as shown by anaesthesia or hypoaesthesia, and none of these was without some ache. There seems to be no justification for this assumption.

Residual deformity—Some broadening of the heel was found in every case. Valgus was present in nine feet, and the one patient who had quite marked valgus had the best subjective result of the entire series. One patient had some slight varus, and he was the only one to complain of a "tired" feeling along the plantar surface of the foot.

Age—The series is small, but of the nine patients over fifty (one sixty-four, not C. 6), two had had excellent results, six very good and one fair. This controverts the argument employed against this procedure in the older patients that the foot is already stiff and further immobilisation will only diminish its eventual range of movement and its function (Lexer-Lopresti 1952).

Failure of fusion—This occurred in three cases or 9·4 per cent. One foot has since been operated upon successfully.

Loss of joint movement—An accurate estimation of this could only be made radiographically, and this was not done. The average loss of ankle movement was 10–25 per cent and of mid-tarsal movement 25–50 per cent. Although the mid-tarsal movement is considerably reduced it seems worth while, despite Conn's (1943) argument, to preserve even 50 per cent of movement, and there was nothing to suggest that this movement was more limited in those who had been operated upon ten years ago than those operated upon more recently.

Infection—There were four infections—a rate of 12·5 per cent. The most serious occurred in a patient of unstable temperament who fell when drunk and disturbed the position of the Steinmann pins and did not report for treatment until the plaster was foul with pus. He was eventually transferred at his own request to the Veterans' Hospital, where he remained under the care of the same surgeon. Due largely to his lack of cooperation and frequent disappearances from the hospital, for which he was eventually barred from treatment, conservative treatment failed and a below-knee amputation was performed eighteen months after the injury. He represents a type of patient in whom the pins should be removed at the conclusion of the operation.

Of the other infections, two cleared rapidly but necessitated prolongation of immobilisation, and the third caused a non-union which has subsequently been operated upon successfully.

DISCUSSION

The treatment of comminuted fractures of the posterior articular facet of the calcaneum by an early arthrodesis is shown by the figures of various authors to be at least capable of good results. Wilson (1933) had 73 per cent good results in patients who returned mostly to heavy work, and 9·1 per cent poor results. Gallie (1943) reported fifty patients with good results. Harris (1946), using the same method of fusion, had thirty-four out of thirty-five patients back to work in six months. Geckeler (1950), using the posterior approach for the less deformed fractures and the lateral approach for the more deformed ones, had his twenty-seven patients back to work in six months, 70 per cent in full work and 30 per cent in light work. Dick (1953) reported that all of the ten patients followed had returned to work within six and a half

months. In the series reported here, within an average time of six and a half months 93 per cent had returned to full gainful employment and 81 per cent had returned to the same job they had had at the time of their injury. Thus the statement of Lindsay and Dewar (1958) requires examination. They divided their results into categories of good and poor only, and therefore the poor results are of more significance than the good ones. In the group that they described as treated by early arthrodesis 51 per cent had poor results as compared with 29 per cent poor results in a similar group treated conservatively. The implication is that whereas conservative treatment leaves much to be desired an early arthrodesis will only increase the likelihood of a poor result. Obviously these conclusions are incompatible with those of Wilson (1927, 1933), Gallie (1943), Harris (1946), Dick (1953), and of this paper; examination of the causes for this incompatibility might be fruitful. The term " early " has been used in this paper to describe the performance of the operation as the primary intention in the treatment of the fracture, and the patients reported have been limited to those operated on within thirty days of the injury. Dick waited until the swelling had subsided after rest, pressure bandaging and elevation. Conn treated his patients in traction for five weeks, and Wilson for no more than two. Harris, after manipulating the fracture, made his decision regarding operation from the radiographs, and the operation was performed soon thereafter. Lindsay and Dewar included all patients operated upon within twelve months of the injury, and although those patients who were operated upon early will be included in this group some who had varying periods of other treatment must also be included in it. The distinction between one month and one year is believed to be of great importance in the treatment of this fracture. It has

TABLE II

COMPARISON OF END RESULTS FOLLOWING PALMER OR GALLIE OPERATION

	Palmer's operation		Gallie's operation	
	Cases	Per cent	Cases	Per cent
Excellent .	6	31·6	5	16·1
Very good .	7	36·8	18	58·0
Fair . .	5	26·3	6	19·3
Poor .	1	5·3	2	6·6

been the experience of those who treated the fracture conservatively that the earlier movements were begun the better the result. Stiffness has been one of the major features of the unsatisfactory results, and it was partly with this in mind that primary fusion has been recommended. The period of immobilisation by spasm or plaster is in many cases lessened and the patient rapidly regains movement after the removal of the post-operative plaster. Dick (1953) did not use plaster at all for this reason but encouraged movement from the beginning. Edmunds (1955) after Palmer's operation reduced its use to four weeks. One of the patients in this series who suffered bilateral fractures, both of which were operated upon and were immobilised in plaster for only ten weeks, very picturesquely described his rigid " flipper " feet until one day he was fortunate enough to stumble on the sidewalk; he suffered severe pain, but has walked normally ever since. A further advantage is that in operating on the fresh fracture the surgeon is able to correct any varus or valgus deformity, which is much more difficult to accomplish when the heel has united in a deformed position. The normal successful uncomplicated primary arthrodesis is not followed by lateral sub-malleolar pain so typical of this injury, and since Lindsay and Dewar have shown that this complaint is not cured by a late arthrodesis one

might conclude that it is the alterations in the soft tissues in the region of the subta ır joint that accompany the deformity that are responsible for this pain. If, therefore, a late art rodesis is not going to be as satisfactory as an early one the surgeon may not run with the h re and hunt with the hounds but is forced to declare himself at the outset as being for or gainst operative treatment. This attitude is exemplified in Smith's (1956) recommendati n that surgical intervention is contra-indicated for eighteen months by "slow continued fu tional improvement in the foot in a patient who can engage in reasonable physical activitie " As this fracture is usually sustained by the manual worker "reasonable physical activity " neans remaining unemployed. A choice is thus made between a probable return to full heavy abour within six and a half months, and a period of unemployment possibly of eighteen n nths, to be followed by an operation with the same subsequent period of convalescence a if it had been performed at the outset, but with less chance of success.

The classification of Maxfield and McDermott (1955) was used in order that some comparison could be made between the results of this method and that of I lmer (Table II).

Although proportionately about twice as many excellent results have followed the I lmer procedure as the Gallie it will be seen that if the very good and excellent groups are dded together the results of the two procedures are not very dissimilar.

SUMMARY

1. The history of open operations on fractures of the calcaneum is reviewed.
2. A report is given of the results of treatment of comminuted and depressed fractures of the calcaneum by primary arthrodesis by a modified Gallie procedure.
3. Of twenty-nine patients, twenty-seven returned to full employment within an average of 6·4 months. Twenty-five of these returned to their previous jobs.
4. Poor tendo calcaneus function and lateral sub-malleolar pain were found to be closely allied; both complaints were absent in the usually successful case and occurred only where there had been some complication.
5. It is contended that subtalar arthrodesis is a successful method of treatment for this fracture, but that the operation should be performed soon after the injury in order that the deformity may be corrected.

We would like to thank Dr G. Williams and Dr G. McDonald for permission to include cases of theirs in this report. We would also like to express our appreciation of the considerable help received from Miss Edna Simmonds in tracing the patients.

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DYSCHONDROPLASIA

Report of a Case

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All too seldom is one given the opportunity of observing the progress of a relatively rare developmental error such as dyschondroplasia. The patient described here has been known to one of us for almost twenty-five years and has been attending Glasgow Royal Infirmary intermittently for fifty-four years.

CASE REPORT

Clinical features—A man, now aged sixty-three, first attended hospital in 1905, complaining of a painful, swollen right foot. He was described as having short arms and dumpy hands at that time. Unfortunately the original case records are no longer available and it is not known whether a diagnosis of Ollier's disease was made. It is known, however, that no operation was done then. About 1912 the phalanges of the right ring finger became greatly enlarged and irregular and were excised by Sir William Macewen and replaced by "a chicken bone graft"; this was gradually absorbed, leaving the redundant and useless envelope of skin which, with the little finger of the same hand, was amputated in 1914. The right hand has required no further surgery. Between 1920 and 1925 several "tumours" from the second right toe and the left great toe were excised; there has been little proliferation of cartilage at these sites since. Between 1914 and 1947 the left hand has had isolated masses of cartilage excised, and amputation of the index, middle and ring fingers. By 1955 a large firm "tumour," originating from the fourth metacarpal, occupied the space between the thumb and little finger of the left hand. This, with the remnants of the second, third and fourth metacarpals, was excised, leaving the thumb and little finger as a functioning pincer. In 1957 further growth, which prevented the use of the pincer, was successfully excised—with restoration of function—but, by the end of that year, a painful proliferation of cartilage on the dorsal aspect of the lower end of the left radius necessitated amputation through the middle of the forearm. Since then the patient has been completely free of pain and there has been no obvious clinical or radiological change in any of the remaining masses of cartilage. In spite of his severe handicap this patient has been able to live alone and to follow such arduous occupations as coal mining and crane driving and is now employed as a mattress maker.

Radiological findings—There is extensive involvement of most of the long bones, metacarpals and phalanges of both upper limbs and of the phalanges of both feet. The short ulna, with curved radius and dislocated radial head on the right side (Fig. 1), is not an uncommon finding. An unusual feature has been a tendency to the development of masses of non-ossifying "tumour" giving a radiological appearance of sarcomatous degeneration. This is seen at the upper angle of the scapula and the costochondral region of the fifth, sixth and seventh ribs on the left side (Fig. 2), the phalanges of the left great toe (Fig. 3), the medial side of the shaft of the second right metacarpal and the medial side of the base of the proximal phalanx of the right middle finger (Fig. 4). No metastatic deposits have ever become apparent.

Pathological findings—Altogether seven specimens are available for study: nodules of cartilage removed from the left hand in 1949, 1951 (twice), 1955 and 1957; the left ring finger amputated in 1952; and the left hand amputated in 1957. Microscopic sections only are available from the first six, whereas gross and microscopic materal is available from the seventh.

Removal of the skin and subcutaneous tissue from this last specimen revealed tumour-like masses of cartilage attached to the dorso-medial aspect of the lower end of the radius, the

FIG. 1

FIG. 2

FIGS. 1 AND 2
Case 1. Figure 1—The right forearm. Figure 2—The thorax. Observe the tumour-like masses attached to the left scapula.

FIG. 3

FIG. 4

Case 1. Figure 3—The metatarsals and toes. Figure 4—The right hand.

medial and dorsal aspects of the first metacarpal and the dorsal aspect of the wrist, and lying free in the space between the first and fifth metacarpals (Figs. 5 and 6). Discrete cartilaginous nodules were also present in the lower end of the radius and in the shaft of the first metacarpal. The median and ulnar nerves had several " stump neuromas " at their lower ends. Blocks of material were taken from the distal end of the radius, the first metacarpal, the scaphoid and the trapezium. These included regions suspected radiographically of being malignant (Fig. 7).

The histological appearance of all of the various specimens did not vary a great deal, though the more recent ones appeared, on the whole, more cellular than any of the others.

FIG. 5

FIG. 6

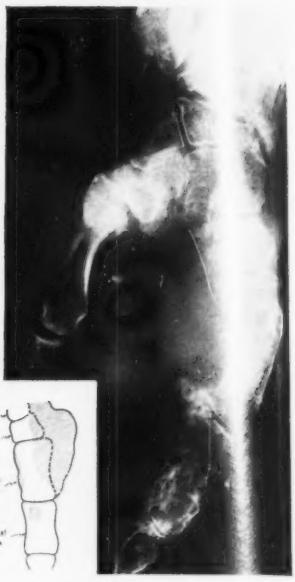

FIG. 7

Case 1. Figure 5—Specimen of the amputated left hand. Figure 6—A section of the left thumb. The diagram shows the area of the " tumour " (shaded) and the outline of the original cortex (dotted). Figure 7—A radiograph of the left thumb. The area of suspected sarcomatous change lies anterior to the first metacarpal.

but even in the earliest specimens there were fields giving essentially the same appearance. All have cellular cartilaginous tissue showing some irregularity of the individual cells, many of which were chondroblastic in type (Fig. 8). The cartilaginous matrix was always abundant. Most of the lesions appeared to be encapsulated, and such cartilage tissue as was seen outside the capsule may well have arisen from clumps of cartilage cells detached at previous operations (Fig. 9). Despite the cellularity, mitotic activity was scanty and true invasive growth was not seen. In the last amputation specimen the " tumour " on the radius was entirely outside the bone and was associated with considerable new bone formation on the outer aspect of the cortex. The masses on the wrist and metacarpal showed continuous cartilaginous tissue both within and on the surface of the bones with destruction of the cortices. There was only slight evidence of osteoclastic absorption of bone, suggesting that growth within the bones is slow. Patchy new bone formation was seen on the shaft of the metacarpal, which corresponded with the radiological appearances. The discrete nodules of cartilage within the radius and the first metacarpal were similar to those already described; some appeared inactive but others were associated with slight osteoclastic absorption, suggesting active growth. The appearance of most of the lesions was compatible with the diagnosis of Ollier's disease, but it was difficult not to regard some as invasive tumours.

DISCUSSION

In the literature on dyschondroplasia there are very few examples of patients who have been followed for more than a short time. Cleveland (1928) had a boy of two whom he observed for seven years, and Fairbank (1951) followed one patient for nineteen years. Our patient appears to be unique in having been under observation for over fifty years. This patient has also provided an opportunity to observe the effect of repeated surgical intervention upon a benign proliferative lesion of cartilage. It is frequently stated, in authoritative text-books and

elsewhere, that sarcomatous change may intervene in this condition. However, a careful search of the literature reveals that the only instances in which this change has been recorded are in the combination of dyschondroplasia with haemangiomata known as Maffucci's syndrome (Carleton, Elkington, Greenfield and Robb-Smith 1942; Strang and Rannie 1950). Despite repeated radiological reports that the lesions in this patient appeared sarcomatous, and the presence of displaced cartilaginous tissue, there is no evidence that true malignant change has occurred.

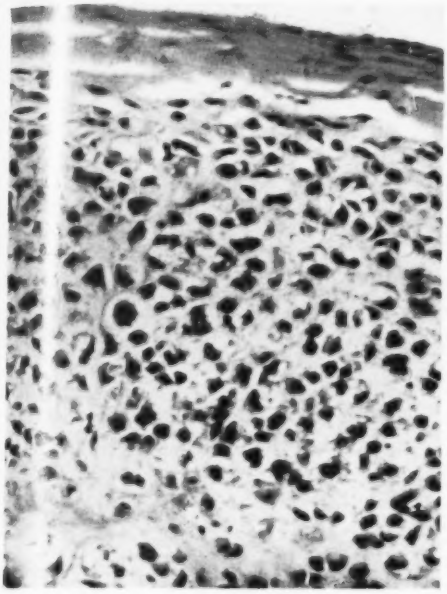

FIG. 8

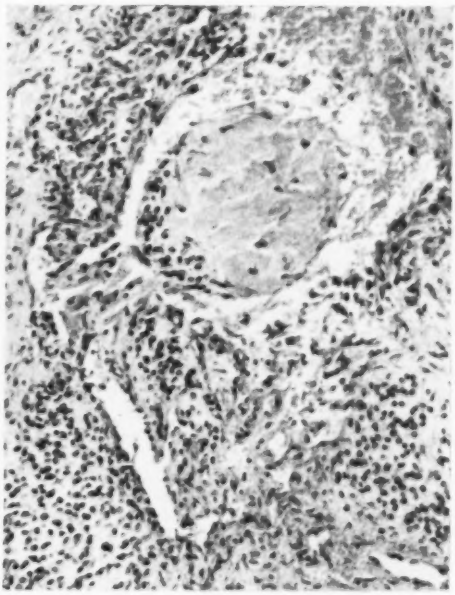

FIG. 9

Case 1—The histological appearance of the mass on the lower end of the radius in Figure 8 (×225) and of that between the first and fifth metacarpals in Figure 9 (×135).

SUMMARY

1. A patient with Ollier's disease, who has been observed for fifty-four years, is described.
2. Repeated operations have been performed and the radiological appearances have been interpreted on several occasions as sarcomatous, but no evidence of malignant change has occurred.

We wish to thank Mr Robin Callander for the drawing in Figure 6.

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A DIRECT LATERAL APPROACH TO THE LATERAL COMPARTMENT OF THE KNEE JOINT

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The usual surgical approach to the lateral compartment of the knee joint can e very unsatisfactory, particularly when a cyst of the lateral semilunar cartilage [lateral meni cus] is present. All authorities are agreed that complete excision of the cartilage is the treatr ent of choice for this condition, and most agree that removal is usually technically difficult. Some surgeons state the problem frankly (Bonnin 1953, Hertz 1955); others admit the diffi ulties when they advise multiple incisions to expose the cyst, or simple removal of the teral semilunar cartilage, leaving the periphery of the cyst to be gradually replaced by fibrous issue.

From 1947 to 1957, 362 knee arthrotomies were performed at Deer Lodge Ho pital. In this series twenty-three patients with cystic degeneration of the cartilage were encoun ered, an incidence of 6·3 per cent. All the cysts were of the lateral cartilage, and all were t ated by total excision of the cartilage. During the treatment of this series a direct approa h to the lateral compartment of the knee was evolved. This technique may have been us d by

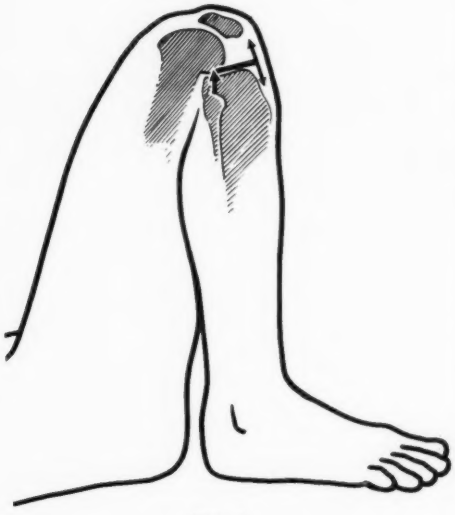

FIG. 1

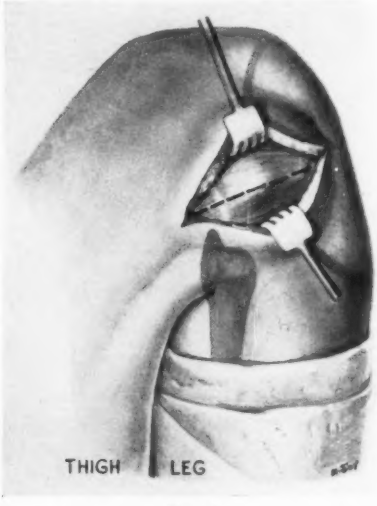

FIG. 2

Figure 1—Position of the limb on the operation table, and the bony landmarks for the skin incision. For simplification, the drapes and the tourniquet have been omitted. Figure 2—The relationship of the fascial incision to the fibres of the ilio-tibial tract. Note the bulge created by the underlying cartilage cyst.

others, but a description of it has not been found in the literature. It gives a wide exposure of this aspect of the knee joint, without danger to important structures, and allows complete removal of the lateral cartilage and the cyst, usually in a single intact mass. The operation, though devised specifically for removal of the cystic lateral cartilage, has been found to be equally useful for the more frequent operation of simple excision of the torn lateral cartilage.

TECHNIQUE OF OPERATION

The operation is done under tourniquet control and the position of the patient is most important. It is essential that the patient be supine, with the limb draped so that full knee movement is possible. The incision into the joint is made with the knee *fully* flexed—and the word fully is emphasised because this is the key to the exposure of the lateral side of the joint. The fully flexed position is best obtained and maintained by placing the foot on the table so that the heel is as close to the buttock as the tourniquet and the drapes will allow (Fig. 1). It should be noted that this position also flexes the hip joint to about 80 degrees, a point of some importance as will be shown later.

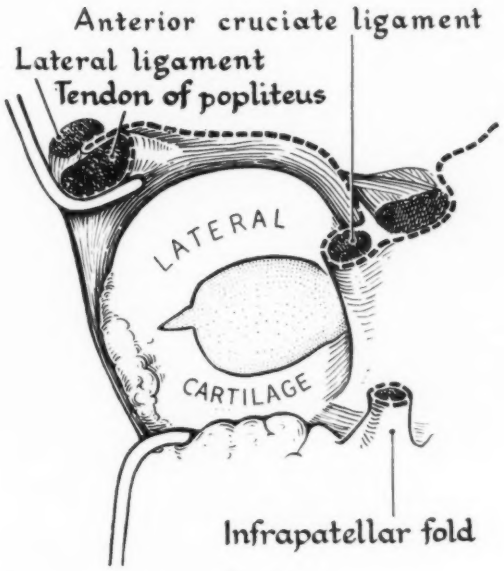

FIG. 3
Diagram of the lateral joint compartment viewed from above, showing the relationship of the incision to the posterior segment of the cartilage; note the retractors in position. The dotted line indicates cut edge of synovium.

The skin incision begins at the lateral joint line where the patellar ligament crosses it, and extends backwards along the joint line to cross an imaginary line drawn between the tip of the styloid process of the fibula and the lateral femoral epicondyle. With the skin and subcutaneous tissues incised, the bright shining fibres of the ilio-tibial tract come into view. At this stage the first advantage of the fully flexed position of the knee joint becomes apparent, because in this position the gently arching fibres of the tract lie almost parallel to the skin incision and joint line (Fig. 2). The incision through the tract is largely, but not entirely, fibre-splitting, as the incision must still follow the joint line and the fibres curve gently along it. The posterior half inch of the fascial incision must be made with care, because at this point the fascia overlies the relaxed lateral [fibular collateral] ligament, but as there is an interval filled with loose areolar tissue separating the two there is not any great danger of incising the ligament, and ordinary surgical precaution will suffice. At this stage the second advantage of the position of the limb becomes apparent: flexion of the hip and knee relaxes the ilio-tibial tract and allows wide retraction of the incision through it without undue force.

In patients with cystic degeneration of the lateral cartilage the cyst will now be partly exposed on its peripheral aspect. The exposure of the cyst is completed by sharp dissection, and here again only ordinary surgical care is needed. As the dissection of the cyst continues, the synovial space is entered along a line just above the upper border of the periphery of the cartilage, or the cyst, as the case may be. Now the entire cartilage can be removed with ease, by freeing the attachment of the anterior horn from the tibia, and dissecting from before backwards. In nearly all cases the cyst and cartilage can be removed in a single mass without any rupture of the cyst. Also, and this is very important, one can see the trunk of the lateral inferior geniculate artery as it passes outside the synovium between the lateral ligament and the postero-lateral aspect of the cartilage. At this site the artery may be ligated.

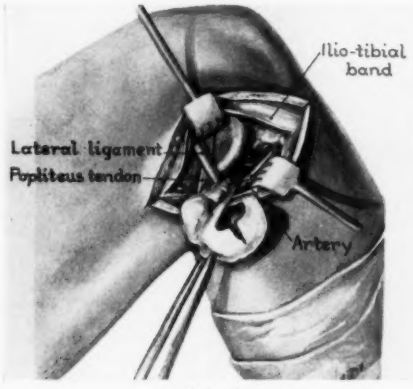

FIG. 4

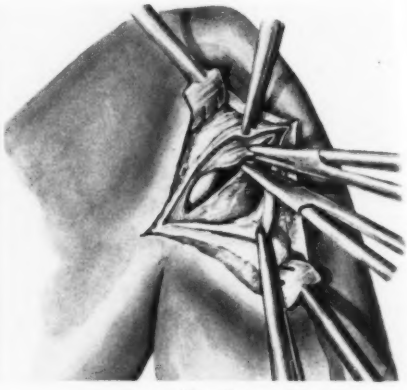

FIG. 5

Figure 4—The important structures of the lateral compartment of the knee joint, as seen through this approach. At this stage the knee may be extended slightly if desired (here it is seen at about 90 degrees of flexion); the fibres of the ilio-tibial band are relaxed, and allow easy retraction and exposure.
Figure 5—The synovial layer is loosely closed with the knee in about 90 degrees of flexion; the knee is usually extended almost fully for fascial closure.

or simply avoided. When a cyst is present it is best to ligate the artery as far back as possible; in operations for cartilage tears ligation, though probably desirable, is not necessary so long as the vessel is kept in view and protected from damage. The control of this vessel which is possible through this approach reduces the risk of haemarthrosis, which is a too frequent complication after operations on the lateral compartment of the knee.

When this approach is used for excision of a torn lateral cartilage the tissue planes are much easier to define, and the dissection is easier. It should be stressed in each case that the position of full flexion throws the lateral ligament and the tendon of the popliteus posteriorly, behind the curving postero-lateral margin of the cartilage, and it is very easy to see the posterior third of the cartilage and to separate this part from the tibia under direct vision (Fig. 3).

Once the cartilage is removed, it is possible to inspect the lateral joint compartment thoroughly, including almost the whole of the articular surfaces of the lateral femoral and tibial condyles, the popliteus tendon, the anterior cruciate ligament, and, by extending the knee and retracting, to view the lateral half of the articular surface of the patella (Fig. 4).

Closure is simple. In patients with cystic degeneration complete synovial closure is neither necessary nor possible; in simple excision of the cartilage for tear, synovial closure is done by interrupted catgut sutures, with the knee at about 90 degrees of flexion (Fig. 5).

The fascial closure is done with the knee extended. Because of the direction of the incision in relationship to its fibres, this layer of the wound almost closes itself on extension of the knee; subcutaneous and skin sutures complete the operation. After operation the routine is the same as for any knee arthrotomy.

ADVANTAGES

1. The incision through the skin follows skin lines and heals well without keloid or spreading of the scar. No important cutaneous nerve is divided or endangered.

2. The incision through the ilio-tibial tract, being largely fibre-splitting, heals well, and in no way weakens the joint or affects its stability.

3. It permits a more complete examination of the lateral joint compartment than is possible through any other single incision.

4. All of the important structures can be examined and most of them treated, should the need arise. The lateral ligament and the popliteus tendon are under direct view and can be protected from damage. The lateral inferior geniculate artery can be controlled with ease.

5. Forcible use of retractors is not necessary, and the knee joint can be protected from the ravages of well-meaning and helpful but athletically powerful junior assistants.

6. Immobilisation after operation is not necessary and knee movements and weight bearing can be resumed as early as after any other method of knee arthrotomy.

SUMMARY

A description is given of a direct approach to the lateral compartment of the knee with the joint fully flexed. This approach has been found useful for excision of cysts of the lateral cartilage, but is also applicable to excision of the lateral cartilage for tear.

I wish to express my thanks to Miss Nancy Joy, Medical Artist to the Department of Surgery, University of Manitoba, for her willing cooperation in producing the drawings for this paper.

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ANATOMICAL VARIATIONS AFFECTING THE SURGERY OF DE QUERVAIN'S DISEASE

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Operations designed to relieve the symptoms in stenosing tendovaginitis of the abductor pollicis longus and extensor pollicis brevis muscles (de Quervain's disease) involve surgical decompression of the osseo-fibrous canal in which the tendons lie. This canal, the first of the extensor tendon compartments at the wrist, is usually said to contain both these tendons in their respective synovial sheaths. Failure in this operation is common and may be related to anatomical variations in these two tendons. Such variations have been known for many years. Quain (1892) observing that the tendon of the abductor pollicis longus was the commonest of all the extensor tendons to vary, and Tillaux (1882) noting that the tendons of the abductor pollicis longus and extensor pollicis brevis might be found lying in separate fibrous compartments.

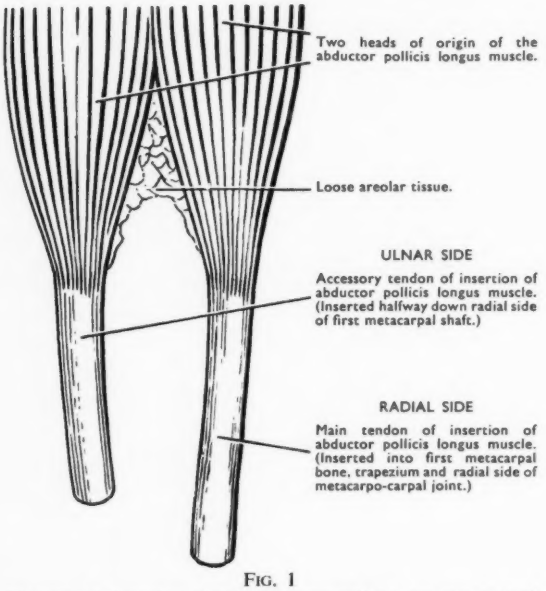
Two heads of origin of the abductor pollicis longus muscle.
Loose areolar tissue.
ULNAR SIDE
Accessory tendon of insertion of abductor pollicis longus muscle. (Inserted halfway down radial side of first metacarpal shaft.)
RADIAL SIDE
Main tendon of insertion of abductor pollicis longus muscle. (Inserted into first metacarpal bone, trapezium and radial side of metacarpo-carpal joint.)

FIG. 1

Diagram of dissection of right abductor pollicis longus muscle of chimpanzee.

A study of the literature indicates that the standard anatomical description is the exception rather than the rule, and that the splitting of the abductor pollicis longus tendon into two or more lamellae is commonly found on dissection of the first extensor compartment of the wrist. Stein (1951) found in a series of eighty-four wrists that 68 per cent exhibited an accessory tendon of the abductor pollicis longus whereas only 4 per cent exhibited a similar accessory tendon of the extensor pollicis brevis. Baba (1954) in a study of 134 dissected wrists found that 132 (98·5 per cent) of these exhibited accessory tendons of the abductor pollicis longus, and, of these, seven showed the accessory tendon to be split into two or more lamellae.

The most important surgical aspect of these variations, normal rather than abnormal—is the incidence of separate osseo-fibrous compartments for these two main tendons or for their accessory tendons, and on this point the literature is scanty. Keon-Cohen (1951) observed in a series of sixty-six dissected forearms that 33 per cent showed the extensor pollicis brevis tendon to occupy a separate compartment. Therefore, in the surgery of stenosing tendovaginitis proper recognition of the presence of these accessory tendons and in particular the presence or absence of a separate osseo-fibrous compartment is of great importance. Decompression of the main osseo-fibrous canal may not relieve the symptoms of the disease if an accessory tendon remains unrecognised and is left compressed in its own fibrous canal.

TABLE I

TABLE OF FINDINGS

Variations in the anatomy of the tendons involved in de Quervain's disease	Numbers	Percentage
Accessory tendons of the abductor pollicis longus	28	56
Accessory tendons of the extensor pollicis brevis	1	2
Tendons of the abductor pollicis longus and the extensor pollicis brevis in separate osseo-fibrous compartments	10	20
Tendons of extensor pollicis brevis lying in a separate canal in the distal part of the main compartment	17	34
The abductor pollicis longus and its accessory tendon(s) lying in a separate osseo-fibrous canal	6	12
The tendon of the extensor pollicis brevis lying in a separate canal in the distal part only, associated with duplication of the abductor pollicis longus	7	14
The accessory tendon of abductor pollicis longus lying in a separate osseo-fibrous canal	2	4

Phylogenetically the abductor pollicis longus and extensor pollicis brevis are differentiations of a common muscle. This muscle appears infantile in this respect because its separation from the abductor pollicis longus is complete only in man and gorilla and the extensor pollicis brevis tendon is always much smaller than that of the abductor pollicis longus. Ayer (1948) described the abductor pollicis longus of the old world monkey as having insertions into the base of the thumb metacarpal bone, the trapezium and the flexor retinaculum [transverse carpal ligament], in this way resembling man. In one specimen he found a small prolongation from the main tendon of insertion, which extended down to the base of the proximal phalanx, such a prolongation probably representing the extensor pollicis brevis muscle. In a recent dissection of the chimpanzee (Pan) an accessory tendon of insertion (Fig. 1) of the abductor pollicis longus was found with an attachment half way along the radial side of the shaft of the thumb metacarpal bone. In the gorilla the abductor pollicis longus tendon divides one centimetre before its insertion into two nearly equal parts. The larger part is inserted into the trapezium and the rest is inserted into the lateral side of the base of the thumb metacarpal bone. The extensor pollicis brevis tendon has a double insertion; though mainly into the lateral aspect of the first metacarpal bone, it is also attached by a very slender tendon to the dorsal surface of the base of the proximal phalanx. Thus one notes a gradation in the extent of differentiation of this common muscle in different species. With such a process still in its phylogenetic infancy it is not surprising that anomalies are to be found in man with great relevance to the surgery of de Quervain's disease.

In this series a study was made of fifty dissected wrists, and particular note was made of the origin of the accessory tendon and of the presence or absence of a secondary osseo-fibrous canal within the first extensor compartment (Table I). An accessory tendon of the abductor pollicis longus was found in 56 per cent of wrists, though in only two wrists was the accessory tendon to be found lying in a separate fibrous canal. In the remainder the abductor pollicis longus with all its accessory tendons of insertion occupied a common canal, which was either the first extensor compartment or the anterior subdivision of this compartment in cases in which an accessory septum separated the extensor pollicis brevis and abductor pollicis longus tendons. The latter type of division of the main compartment into two parts, one for the extensor pollicis brevis and its accessory tendons, the other for the abductor pollicis longus and its accessory tendons, was found in 20 per cent of wrists. Such a division was easily recognised, though a limited surgical incision might have misled one into mistaking the anterior

compartment containing the abductor pollicis longus and its accessory tendon to be the whole of the first extensor compartment and its contents (Fig. 2).

The most interesting type of subdivision of the first extensor compartment affected the

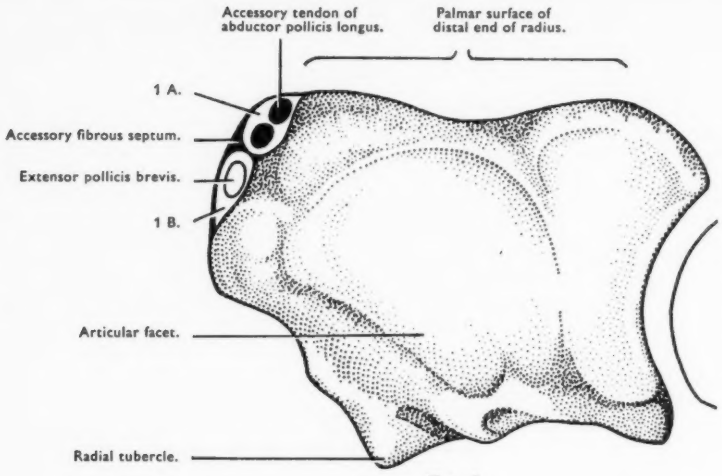

FIG. 2

Distal view of right radius (*seen end on*). 1A—Subdivision of first extensor compartment containing abductor pollicis longus plus accessory tendon. 1B—Subdivision of compartment containing extensor pollicis brevis.

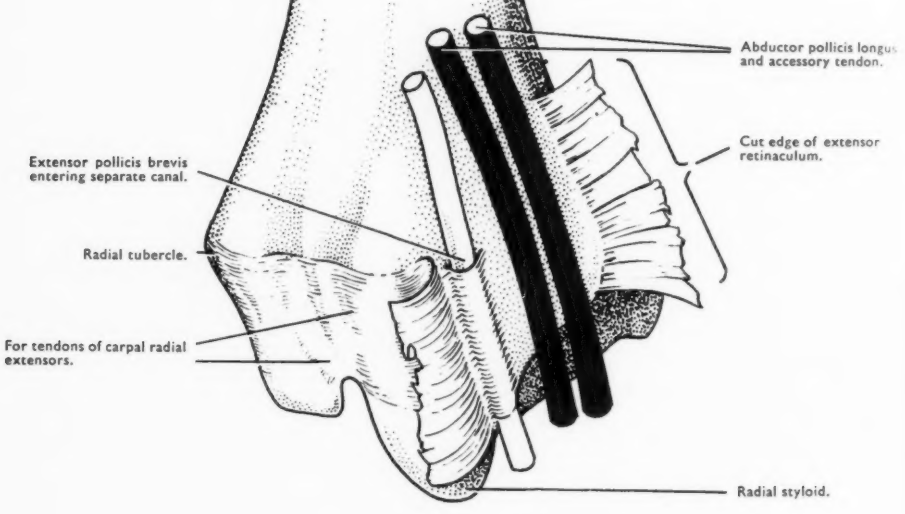
Abductor pollicis longus and accessory tendon.
Cut edge of extensor retinaculum.
Extensor pollicis brevis entering separate canal.
Radial tubercle.
For tendons of carpal radial extensors.
Radial styloid.

FIG. 3

Lateral view of distal end of right radius.

tendon of the extensor pollicis brevis. In 34 per cent of cases this tendon was found entering a separate canal, present only in the distal part of the compartment, often only the distal one-quarter. This separate osseo-fibrous canal lay deep and was found only after displacement

of the overlying tendon or tendons of the abductor pollicis longus (Fig. 3). In each case the canal was small and the lumen seemed only just large enough to accommodate the tendon. Such circumstances, with a small and separate fibrous canal housing the extensor pollicis brevis tendon, would be aggravated in a corresponding stenosing tendovaginitis: furthermore, such a canal could well pass unobserved during a routine decompression of the first extensor compartment.

SUMMARY AND CONCLUSIONS

Attention has been drawn to the variations found in the anatomy of the tendons of the abductor pollicis longus and extensor pollicis brevis muscles as they lie in the first extensor compartment of the wrist. Such variations involve reduplication of the abductor pollicis longus tendon and more rarely the extensor pollicis brevis tendon. An accessory tendon may occasionally lie in a separate osseo-fibrous canal. It is not unusual to find the abductor pollicis longus and extensor pollicis brevis tendons lying in separate compartments, because an accessory fibrous septum is subdividing the first extensor compartment into two parts. Furthermore, the extensor pollicis brevis tendon may also lie in its own separate fibrous canal in the depths and the more distal part of this common compartment.

Such variation could lead to two possible misinterpretations during the course of surgical decompression for de Quervain's disease and these misinterpretations could reasonably be linked with the failure rate for this particular operation.

1. The finding of the abductor pollicis longus and its accessory tendon in a single compartment (12 per cent of wrists in the series) after a limited surgical incision could be mistaken for the abductor pollicis longus and extensor pollicis brevis tendons. Such a mistake would lead to failure to decompress the extensor pollicis brevis.
2. A failure to identify the deeper-lying separate canal for the extensor pollicis brevis in the distal part of the compartment would again be responsible for failure to decompress the extensor pollicis brevis (14 per cent of wrists in this series).

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HYPEREXTENSION INJURY OF THE CERVICAL SPINE WITH RUPTURE OF THE OESOPHAGUS

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A man aged seventy-three years was out walking with his hands in his trouser pockets when he stumbled and fell forwards on to his face. The first assessment of the result of the fall was that he had broken his glasses and sprained his neck. He complained of pain in the neck and dysphagia, and two days later, when he was first seen by his family doctor, the only physical signs elicited were local tenderness and stiffness in the neck.

A week after the fall the patient became very ill and a swelling appeared in the right side of his neck. He was admitted to hospital. His general condition was poor, and he had respiratory embarrassment; the temperature and pulse were normal on admission, but rose soon afterwards; the blood pressure was 130/70 millimetres of mercury. The right side of the neck was swollen and inflamed. There were no abnormal neurological signs.

FIG. 1

FIG. 2

Radiographs of the neck in flexion (Fig. 1) and in extension.

Radiographs revealed cervical osteoarthritis. There was subluxation of C.4 on C.5, and the disc space between C.6 and 7 was almost obliterated, with lipping of the adjacent margins of the vertebral bodies (Fig. 1). A lateral radiograph with the neck extended showed that this interval had opened in front to almost four millimetres and contained gas (Fig. 2). There was no evidence of recent bony injury.

Treatment and progress—Under general anaesthesia the swelling in the neck was incised and a quantity of pus and foul-smelling gas escaped. The wound was drained and chemotherapy

was instituted. Coliform bacilli, haemolytic streptococci and some yeasts were cultured from the pus.

Since the patient was unable to swallow anything but sips of water, intravenous fluids were given. The temperature continued to fluctuate, but he seemed to be holding his own until he collapsed suddenly a week after admission. He became semi-comatose and cyanosed with marked respiratory distress, and signs of bronchopneumonia appeared. He subsequently lapsed into coma and died.

Necropsy revealed rupture of the anterior longitudinal ligament, so that on extension of the neck the bodies of C.6 and 7 gaped apart. The spinal cord was seemingly undamaged. There was a tear two centimetres long in the back of the oesophagus to the left of the mid-line one and a half centimetres below the level of the cricoid cartilage. The tear was ascribed to the sharp edge of the seventh cervical vertebral body. There was pus in the retropharyngeal space and in pockets throughout the soft tissues of the neck. There were extensive bronchopneumonia and acute non-purulent mediastinitis. The skull, meninges and brain showed no abnormality.

COMMENT

In this case an extensive injury of an osteoarthritic cervical spine with rupture of the anterior longitudinal ligament caused a tear in the posterior wall of the oesophagus which led to mediastinitis with terminal bronchopneumonia.

Several cases of rupture of the oesophagus from external violence are recorded. In these cases severe violence was applied to the abdomen or thorax and the oesophagus ruptured in the posterior mediastinum (Murdoch 1928, Lomax 1906, Aldrich and Anspach 1939). Penetration of the oesophagus by foreign bodies or during oesophagoscopy is also well recognised.

In recent years Barnes (1948) and Taylor and Blackwood (1948) have drawn attention to the vulnerability of elderly subjects with cervical osteoarthritis to hyperextension injuries, and this case illustrates the far-reaching consequences of a relatively trivial injury in a predisposed subject.

I am indebted to Mr R. C. Murray for permission to publish this case and for his help in preparing this communication.

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AN AID FOR THE SEVERELY PARALYSED UPPER EXTREMITIES

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With the introduction of functional splinting, patients previously disabled through paralysis of the upper limbs can, by using appropriate activator muscles either in the shoulder girdle or lower extremities, be made more independent. By means of suitable devices such movements as pinching, gripping and flexion and extension of the elbow are possible in the otherwise paralysed limb (Schottstaedt and Robinson 1956).

There still remains a small group of patients in whom complete flaccid paralysis includes the muscles of the shoulder girdle as well as those of the upper limbs. This particular problem occurs most commonly in poliomyelitis, and in some patients with tetraplegia. In such cases the patient is unable to undertake any of the activities of ordinary daily living.

In an attempt to rehabilitate such a patient, a new feeding apparatus has been designed which enables the patient, by foot and knee movements, to raise or lower a fork or spoon, to move either of these implements to any point over a plate of food, and to control them through any combination of arcs and angles necessary.

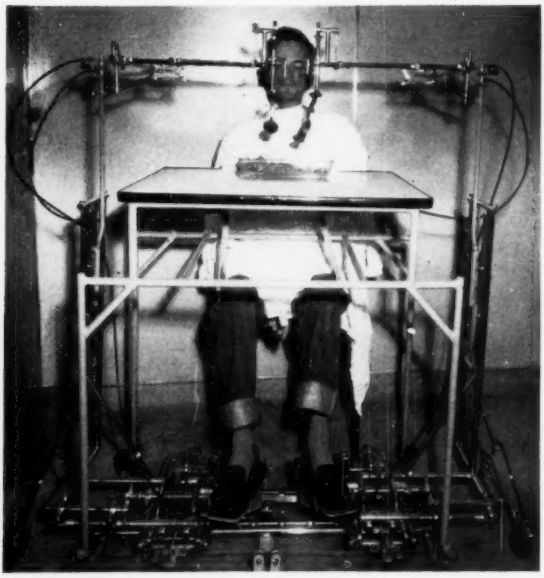

Fig. 1
The apparatus.

The indications for the use of the apparatus depend on how much power remains in the lower limbs. If the remaining power is good the apparatus is unnecessary, for more standard functional bracing will be possible and will render the patient much more independent. But if muscle power is less than that required for functional splints (Medical Research Council's grade 4) this particular type of apparatus is useful.

The apparatus, shown in Figures 1 to 3, was designed and built at the Princess Margaret Hospital for Children, Perth. The two foot plates or platforms are jointed to permit plantarflexion and dorsiflexion as well as medial and lateral rotation. They are mounted on ball-raced trolleys, moving forwards and backwards in channels as the knees are extended or flexed. Both the flexor and extensor trolleys carrying the foot platforms are mounted on two further trolleys which permit medial or lateral movement with adduction or abduction of the lower limbs. These moving parts are linked mechanically to the fork and spoon. Light lateral pressure of the knees against two levers activates two further controls. Appropriate combinations

of lower limb movement thus enable the patient to develop, with practice, a smoothly controlled action for feeding, reading and certain needs of the toilet. The main disadvantage of the equipment is its bulk.

FIG. 2
Detail showing the mounting of the implements.

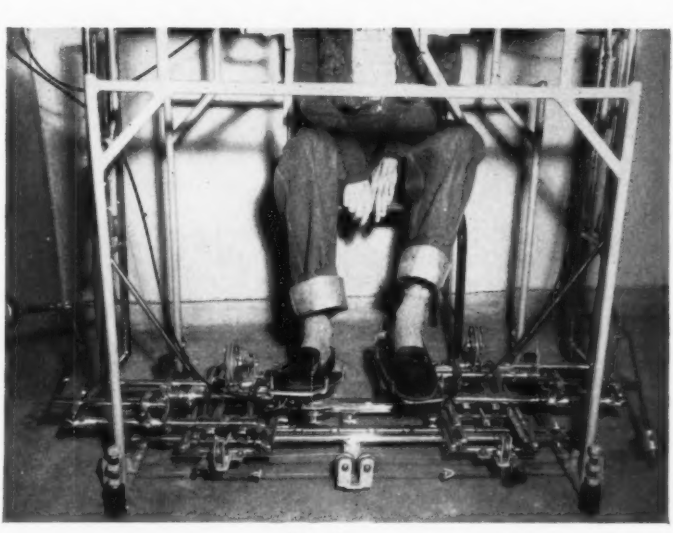

FIG. 3
Detail of the controlling mechanism.

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ANATOMY OF THE CALCANEAL TENDON OF THE RABBIT

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Although Mayer (1916), Edwards (1946), Brockis (1953) and others have made important contributions to the study of tendons, a recent text-book on the surgery of repair as applied to hand injuries states that detailed studies of the anatomy and physiology of tendon are rare (Rank and Wakefield 1953). Before embarking on an experimental inquiry on the degeneration, rupture and regeneration of tendons in which the calcaneal tendon of the rabbit was to be used, it was therefore decided to examine this tendon in detail, with special reference to the sheath and blood supply. Standard works on the rabbit (Bensley 1945) do not contain this information.

PREVIOUS EXPERIMENTAL STUDIES

Tendon sheath—The accepted description is based on that of Mayer (1916) and little else has been added to it since. A tendon sheath is found only where a tendon is forced to turn a corner. The sheath (or rather the cavity formed by it) is said to correspond to a joint cavity because it too is a circumscribed cavity containing a " synovia-like " fluid. When a tendon—such as the tendo calcaneus—pursues a straight course it has therefore no sheath. Mayer (1916) does not make it clear what the covering of the tendo calcaneus actually is, but it seems to be the paratenon, which is said to be related to those parts of tendon devoid of sheaths. The paratenon is variously described as a loose fatty areolar tissue, a vascular fatty connective tissue rich in elastic fibres or a loose fatty tissue investing the tendon, and is found above the level of the sheath deep to the fascia. The ability of a tendon to glide is based fundamentally on the peculiar elasticity of this tissue. The epitenon is a delicate, almost microscopical layer on the surface of the tendon, giving rise to the endotenon which penetrates and divides the tendon into bundles. The epitenon is derived from the mesotenon, the latter structure conveying vessels to the surface of the tendon and described only in relation to tendons with synovial sheaths.

Bunnell (1944) described the continuity between the paratenon and epitenon by loosely coiled fibres (Mayer's (1916, 1952) often quoted " watch springs ") which coil and uncoil on movement. These fibres are dragged first in one direction and then in the other. However, the description goes on to state that the paratenon, being attached to the surrounding fascia, remains stationary, whereas the epitenon, being adherent to the tendon, moves with it.

Edwards (1946), quoting Mayer (1916), described the paratenon as a very loosely woven connective tissue surrounding the tendon, functioning as an elastic sleeve and allowing free movement of the tendon against the tissues while maintaining their continuity.

Skoog and Persson (1954) described the paratenon of the tendo calcaneus of the rabbit as the connective tissue outside the peritenon (that is, the epitenon) and not belonging to the tendon structure proper; the peritenon as the connective tissue covering the surface of the tendon. The latter is also referred to as a specialised connective tissue capsule.

Blood vessels—In tendon with paratenons (that is, tendons without synovial coverings) Edwards (1946) described vessels coursing through the paratenon (areolar sleeve) at frequent and regular intervals to reach the surface of the tendon. They arose from vessels lying in the vicinity and did not appear to have a specific origin and course. This has become the generally accepted description of the arrangement of the vessels in tendon with paratenons. Skoog

Terminology—To conform with the anatomical nomenclature used by this Journal, the structure usually known to laboratory workers as the tendo Achillis is referred to here as the tendo calcaneus or calcaneal tendon.

and Persson (1954) described the epitenon (called by them the peritenon) as having a specialised vascular system. Vessels also reach the surface of the tendon from the muscle. The intratendinous vessels were fully described by Edwards (1946) and Brockis (1953), and will not be described here except to state that a free communication exists between the extratendinous and intratendinous vessels.

MATERIALS AND METHODS

The tendo calcaneus in thirty full-grown Belgian rabbits of either sex were used. The animals were anaesthetised with intravenous Nembutal injected into the marginal vein of the ear and the anaesthetic was continued with open ether administered by means of a mask. While still alive the anaesthetised animal received an injection of approximately 200 cubic centimetres of a 4 per cent aqueous suspension of Berlin blue at a pressure of 200 millimetres of mercury into the abdominal aorta to demonstrate the vessels. The heart continued to act as a venous pump allowing almost full filling of the vascular system of the lower limbs. The animal was then killed with an overdose of ether. The injection techniques were like those employed by Trueta, Barclay, Daniel, Franklin and Prichard (1947). The iliac vessels were tied and the hind limbs were disarticulated, skinned and fixed in 10 per cent formal saline.

The entire tendo calcaneus and its coverings together with the calf and calcaneum were dissected and cleared by the Spalteholz (1914) method. Several unfixed fresh specimens (in which the paratendinous tissues remain transparent for a short time) were examined with teasing needles under the dissecting microscope. Frozen longitudinal and transverse sections stained with haematoxylin and eosin were also examined. In both fixed and fresh specimens the injected vessels were easily followed to their terminations. In ten specimens the calcaneum was decalcified in 5 per cent formic acid in 70 per cent alcohol (Cowdry 1952) and longitudinal sections three millimetres thick from the musculo-tendinous junction to the bony insertion were cut free-hand with a safety razor blade and cleared. Similar longitudinal and transverse celloidin-imbedded sections (20 μ) were stained with haematoxylin and eosin and van Gieson's stain.

FINDINGS

The findings will be discussed under the following headings. 1) Macroscopical appearances of the tendo calcaneus and related structures. 2) Observations with the dissecting microscope. 3) Microscopical appearances.

MACROSCOPICAL APPEARANCES

Soleus and plantaris tendons—The soleus tendon (Skoog and Persson 1954), often itself referred to as the calcaneus tendon, is the largest of the tendons which form the tendo calcaneus [Achillis]. It arises directly from the soleus muscle and is slightly twisted in its long axis. After turning round the posterior aspect of the calcaneum to reach the plantar aspect it expands to embrace the bone at its insertion. The musculo-tendinous junctions of the gastrocnemius, on the other hand, have an oblique attachment to the soleus tendon and form a sleeve or cuff which envelops the origin of the plantaris tendon. The latter is often quite a large structure. There is a groove of varying depth in the soleus tendon in which the plantaris tendon lies, so that in cross-section within the sheath two, and sometimes three, tendons may be seen. The soleus tendon also receives a strong slip of insertion from the semimembranosus muscle.

The soleus tendon becomes fibrocartilaginous at the posterior aspect of the calcaneum, where it is subjected to the pressure of the plantaris tendon on its way to the sole of the foot, and is obviously associated with the gliding of the latter tendon.

The tendon sheath—The area occupied by the tendo calcaneus [Achillis] is devoid of fat. On removal of the skin a firm fibrous sheath is immediately encountered which envelops the entire length of the tendon and seems to be derived from the deep or subcutaneous fascia of the leg. Through this, the tendons with the vessels lying on their surfaces can be seen (Fig. 1).

When this sheath is incised longitudinally the tendons are found to have smooth shining surfaces of synovial appearance (Fig. 2). On the surface of the tendons a vascular membrane is seen which because of its elasticity can in the fresh state be moved slightly with a probing needle. In formalin-hardened specimens this membrane is tough and closely adherent to the surface of the tendon and cannot easily be moved. The space between the outer firm sheath and the membrane on the surface of the tendon is occupied by a substance of fluid consistency and contains little or no tissue to the naked eye (it is essential to do the dissection in the fresh

FIG. 1

FIG. 2

Figure 1—Sheath of tendo calcaneus of rabbit; arterial injection 4 per cent Berlin blue. A window has been cut in the paratenon to reveal the tube-like structure in which the tendon lies. Figure 2—Sheath of tendo calcaneus of rabbit; arterial injection 4 per cent Berlin blue. Paratenon and epitenon, posterior view. The paratenon or sheath is incised longitudinally and held open with concealed stainless steel sutures. The smooth almost synovial surfaces can be seen.

specimen to appreciate these appearances). It is presumed that the membrane on the surface of the tendons is the *epitenon*. The *paratenon* is represented here as the firm outer sheath which contains no fatty tissue.

However, along the anterior or deep aspect of the paratendinous sheath there is a condensation of tissue which blends with the epitenon and prevents the tendons from being withdrawn from the sheath (Fig. 3). This undoubtedly represents a mesotenon, the only means whereby vessels from the paratenon can reach the epitenon. The mesotenon contains a little fat. Proximally, the paratendinous sheath and epitenon blend with the fascia and sheath of the muscles. On injecting india ink into the sheath the fluid passes proximally

under a minimum of pressure over the muscles, suggesting that no special barrier encloses the sheath. Distally the layers blend with the tissues around the heel.

OBSERVATIONS WITH THE DISSECTING MICROSCOPE

The sheath—The paratendinous sheath consists of layers of connective tissue which can be peeled off with teasing needles. Deep to this, occupying the space between the paratenon and epitenon, the semi-fluid material is encountered which contains a filmy homogeneous material which serves to retain the fluid. The epitenon is apparently a single membrane adherent to the surface of the tendon but slightly movable in the fresh state as already described.

The blood vessels—The injected vessels can easily be traced to their termination. The vessels of the paratendinous sheath arise from the main arteries of the leg. Because of the laminated nature of the sheath they are arranged in layers which encircle the tendons with but little communication between the layers. They are arteriolar in size and branch repeatedly and are accompanied by venae comites. However, along the deep aspect of the tendon several vessels are conveyed by the condensation of connective tissue described here as a mesotenon, to join the vessels on the surface of the tendon. It must be stressed that no vessels are found crossing the semi-fluid space beneath the sheath.

The vessels of the epitenon are derived proximally from superficial and deep muscular branches and distally from vessels in the region of the heel. They are joined by the vessels of the mesotenon already described. They lie longitudinally in grooves formed by the tendon fasciculi. Along the edges of the tendon the arteries are larger than those on the intervening surfaces and are derived from the terminal branches of the saphenous and superficial sural arteries. When the epitenon is manipulated in the anaesthetised animal, the vessels in it disappear from sight.

From the vessels of the epitenon branches pass between the fasciculi in the endotenon and join the intratendinous longitudinal anastomosis. This arrangement has been fully described by Edwards (1946), but it is worth mentioning that the preparations show very well the compression exerted by the tendon fasciculi on the capillaries (Fig. 4) which connect the longitudinally disposed vessels in the tendons and which are believed to play a part in the intratendinous lubricating mechanism (Howard 1941, Edwards 1946).

FIG. 3

Sheath of tendo calcaneus of rabbit; arterial injection 4 per cent Berlin blue. Paratenon and epitenon, anterior view. Part of the mesotenon conveying vessels to the epitenon is displayed.

MICROSCOPICAL APPEARANCES

Transverse sections clearly demonstrate the composite nature of the tendon, the condensation of the deep fascia forming the sheath being seen to contain two and sometimes three distinct tendons, depending on the depth of the longitudinal groove in the soleus tendon (Fig. 5). The paratendinous sheath is composed of dense encircling fibres. The epitenon is a layer adherent to the tendons and presents an artificial appearance because of the fixation and imbedding. Transverse and longitudinal sections show that continuity is established between the sheath and epitenon by delicate fibres which colour pink with van Gieson's stain and are presumably collagen. They contain no cells however—and it is possible

that the many clefts between them are also artifacts. Elastic stains reveal no elastic fibres. The connective tissue is densely arranged in the anterior or deep aspect of the tend ons to form the mesotenon and here the fibres can be seen to spread out over the surface of the tendon to form the epitenon.

The injected blood vessels are clearly seen, disposed as previously described. No essels are seen to cross to the tendon except anteriorly in the region of the mesotenon.

In summary it may be said that the appearances obtained by macroscopical examin tion, with the dissecting binocular microscope and microscopically, reveal that the tendo calc neus of the rabbit is enveloped in a firm sheath, deep to which there is an acellular space occ pied by a substance of nearly fluid consistency. This sheath and space contain the tendon and epitenon, and the sheath and epitenon are connected by a condensation of tissue ke a mesotenon. The vessels are therefore arranged in two distinct sets which are largely indepe dent

FIG. 4

FIG. 5

Figure 4—Intratendinous longitudinal anastomosis, soleus tendon of rabbit. Arterial injection 4 per cent Berlin blue; Spalteholz cleared. (×50.) The longitudinal vessels are parallel to the tendon fasciculi and the connecting capillaries are often compressed. Figure 5—Transverse section of tendo calcaneus and sheath (rabbit). Arterial injection 4 per cent Berlin blue. (×130.) The space beneath the sheath is occupied by a delicate homogeneous material. No vessels cross this space except by the mesotenon. Note the vessels in the paratendinous sheath in the epitenon on the surface of the tendon. Van Gieson and elastic stain.

of each other and which communicate only by way of the mesotenon. Thus the sheath and the vascular arrangements closely simulate that of truly synovial tendons, a state of affairs not appreciated at the beginning of this inquiry. On movement of the fresh injected specimens the paratendinous sheath and its vessels remain stationary, while the epitenon and its vessels and the tendon are seen to have an excursion of two to three centimetres.

DISCUSSION

Although it is true that, as Mayer (1916, 1952) repeatedly stated, wide variations between tendon sheaths exist, it was found impossible entirely to reconcile his description with the present findings on the tendo calcaneus of the rabbit. This did not seem to be due to a confusion of terminology. In the tendo calcaneus of the rabbit the paratenon was a distinct sheath and the epitenon a membrane easily seen macroscopically. Between the two there was a cavity which closely resembled that in truly synovial tendons and it seemed that there was little fundamental functional difference between the two types.

The chief difficulty in accepting the *general* arrangement of the connective tissue coverings for the tendo calcaneus of the rabbit as described by Mayer (1916) is that the *paratenon* cannot be adequately defined. What Mayer (1916) described as the *paratenon* (between the " fascia " and tendon) in the tendo calcaneus of the rabbit was found to be a space containing an

infinitesimal amount of material and an acellular area scarcely to be distinguished without the aid of a binocular microscope from a synovial compartment. The ease with which fluid entered it strongly suggested the presence of an actual space or cleft. No fatty tissue existed except in relation to the mesotenon and no elastic fibres were found. The surfaces of the tendon were smooth and glistening as in synovial tendons. Fixed stained specimens give no idea of the state of affairs in the living or fresh specimen.

Again, the anatomy of the blood vessels was found to be similar to that of synovial tendons, no doubt because of the wide excursion of the tendon. Thus, arrangement of the blood vessels for tendons with paratenons described by Edwards (1946) does not hold for the tendo calcaneus of the rabbit.

In discussing the chemistry of the mesodermal ground substances Meyer (1957) stated that the connective tissues are a highly integrated organ, the maintenance and function of which depended on cellular metabolism. The cellular elements presumably played a more important role than either the ground substances (of which there were many) or the formed elements. Synovial fluid is a ground substance composed largely of hyaluronic acid. No biochemical analysis of the gliding material of paratenons has been made, but it probably is closely akin to synovial fluid with the addition of mucopolysaccharide. At any rate the demonstration of a high hyaluronic acid content in this material would prove its functional role of a lubricant. As already indicated it is quite acellular and homogeneous and is obviously produced by the connective tissue cells of the paratendinous and epitendinous sheaths by the stimulus of gliding. It is only after fixation that some delicate fibres are revealed, and elastic tissue preparations used in this study revealed no elastic fibres. It is a mistake to consider this area of the tendo calcaneus of the rabbit (and probably of similar tendons as well) as composed of fibres which are pulled in various directions. A delicate gliding mechanism requires a much more fluid medium than this to function properly.

The human tendo calcaneus is anatomically and physiologically comparable to that of the rabbit. The plantaris tendon has now become a vestigial structure. The corresponding mesotenon is a thicker, fat-laden structure situated on the deep aspect of the tendon across which many vessels pass to reach the sides of the tendon. The immovable sheath or paratenon, through which the movable tendon and epitenon can be seen, is the same, and effectively separates the subcutaneous fat from the structures beneath. If the sheath in man is injected with saline (either at operation or in the cadaver) a small amount of delicate tissue only is displayed, which is mainly acellular collagen. Staining reveals no elastic fibres.

If the human tendo calcaneus is examined at operation (under general anaesthesia and with a tourniquet applied) the excursion between the paratenon and epitenon is found to be about two centimetres and sometimes more. Saline injected into the sheath passes easily along the tendon and over the muscles. On opening the sheath some of the saline is confined to the surface of the tendon by a small quantity of delicate tissue which stains pink with van Gieson and seems to be composed of collagen fibres, but much of it is lost. The surface of the tendon is smooth and glistening. As in the rabbit, it is clearly seen that because of the length of the excursion there is considerable friction between the paratenon and epitenon on vigorous movement. The anatomy is scarcely distinguishable from that of a synovial tendon.

These findings may perhaps be related to pathological states of the tendon. Spontaneous or pathological rupture of the tendo calcaneus often occurs in healthy adults. The closely enveloping vascular sheath and the gliding mechanism seem to have a bearing on the problem. Any alteration of the vascular environment (as produced by tenosynovitis or by friction on vigorous movement) is likely to be accompanied by changes within the tendon. A recent publication on spontaneous rupture of the tendo calcaneus in man (Arner and Lindholm 1959) supports my view as to the etiology of this puzzling condition, but gives few exact details as to how the vascular changes are brought about. It is possible that the protective function of the epitenon described by Skoog and Persson (1954) may break down. Many workers

(Catchpole 1957, Marbach 1957) are coming to believe that the cellular elements of the connective tissues are dependent on a normal environment, and that any noxious influence quickly affects them. In this way the extracellular components which are dependent on them are seriously weakened. The anatomical and physiological findings reported here may perhaps provide an explanation for the spontaneous rupture of the strongest tendon in the body. Evidence for this was put forward in a short preliminary report (Nisbet 1957).

SUMMARY

1. Certain macroscopical and microscopical features of the tendo calcaneus of the rabbit are described and illustrated, and the vascularisation as revealed by Spalteholz clearing is presented.
2. The vessels of the epitenon are chiefly derived from proximal and distal sources.
3. The vessels of the paratenon are derived from the main arteries of the leg.
4. The two vascular systems are largely independent of each other except along one edge of the tendon by way of a mesotenon.
5. The paratenon, epitenon and mesotenon and the related vessels are comparable to those found in tendons with synovial sheaths. By inference and from evidence obtained by dissection on the living human subject it is suggested that the arrangements are similar in the human tendo calcaneus.
6. Considerable friction develops on movement between the surfaces of the paratenon and epitenon. This might be significant in pathological states of the human tendon.

This research was conducted in the Nuffield Orthopaedic Centre, Oxford, England. I am obliged to Professor J. Trueta for criticism in the conduction of this inquiry and to Mr A. Mann and Mr D. W. Charles for their technical assistance. Dr G. Schofield, Department of Anatomy, Otago Medical School, was most helpful in the preparation of the paper.

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THE VASCULAR CONTRIBUTION TO OSTEOGENESIS

II. Studies with the Electron Microscope

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In a previous paper (Trueta and Morgan 1960) the vessels adjacent to the growth cartilage were studied by the light microscope after vascular perfusion. In the present work our main findings in a similar study made with the electron microscope are reported. The method was used primarily as an aid to the interpretation of sections examined under the light microscope. For this purpose it was found that negative magnifications in the range $\times 700$ to $\times 3{,}000$, while giving all the resolution that is required, provided photographs which are readily compared with those obtained with the light microscope.

METHOD

Specimens were prepared as described by Trueta and Morgan (1960). Growth cartilage was excised, together with the adjacent bone, and pieces not more than two millimetres across and one millimetre thick were fixed in formalin (pH 7·2–7·6). These were embedded

FIG. 1

FIG. 2

Figure 1—Injection medium (barium sulphate crystals) and wall of vessel. ($\times 5{,}250$.). Figure 2—Canaliculi in bone, containing cell processes. ($\times 6{,}560$.)

in a mixture of butyl and isobutyl methacrylate and sectioned with a glass or diamond knife. The embedding medium was removed with amyl acetate (Little 1957). As sections examined were of the order of one millimetre or slightly more across there was little difficulty in finding areas for comparison in the sections examined by the light microscope.

The appearance under the electron microscope of an injected vessel containing a mass of a fine barium suspension (Micropaque) is characteristic. The vessel shown in Figure 1 is

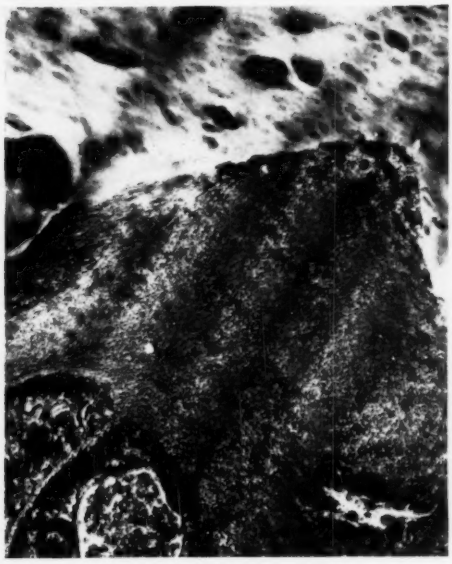

FIG. 3

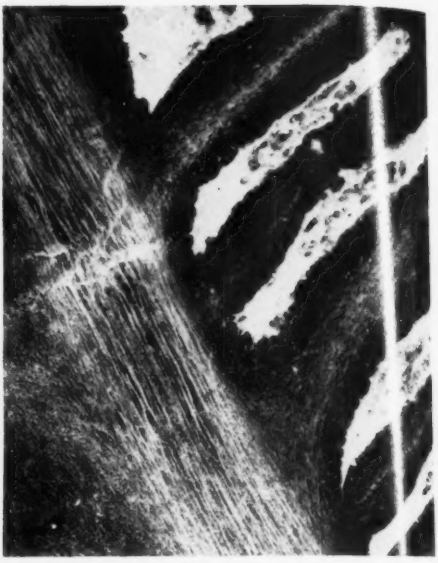

FIG. 4

Figure 3—Top of epiphysial cartilage, in contact with calcified cartilage. (×2,625.) Figure 4—Column of cells, adjacent to orientated collagen fibrils. (×2,625.)

FIG. 5

FIG. 6

Figure 5—Transverse section in proliferative zone, showing two nuclei in one cell. (×2,625.) Figure 6—Two cells, unseparated by matrix (human specimen). (×3,935.)

typical. In some areas of injected specimens erythrocytes were observed in the vascular lumen either alone or associated with particles of barium.

The growth plates of rabbits provided most of the specimens used in this study. A few from rats and humans have also been used for comparison.

RESULTS

For the description of findings the order adopted in the first article of this series will be followed, starting at the epiphysial side of the growth cartilage and ending in the area of bone formation in the metaphysis.

Particular attention will be paid to three of the main factors involved in growth: firstly, the position and main characteristics of the vessels adjacent to the epiphysial cartilage on both its epiphysial and metaphysial sides; secondly, the cartilage cells and their division; and thirdly, the matrix and its calcification.

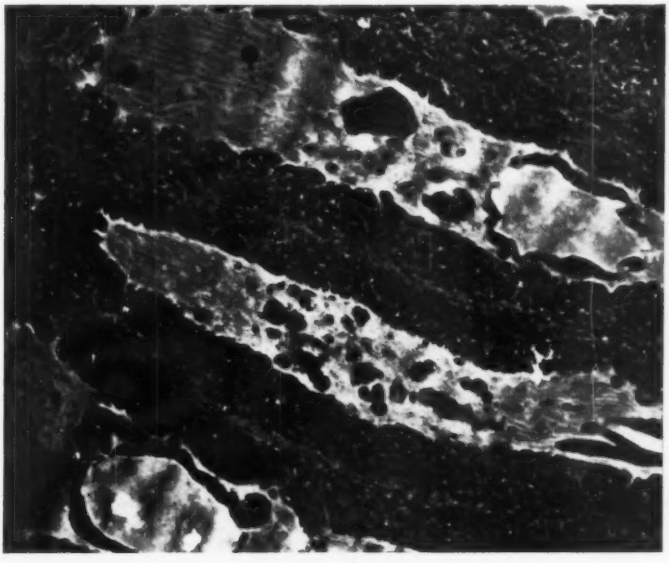

FIG. 7
Cells separated by newly formed matrix. (×4,800.)

Bone plate—In longitudinal sections along the main axis of the epiphysial cartilage the bone plate appears as a massive calcified area with cells (osteocytes) totally surrounded by bone. A number of observations of the cell to cell system of canaliculi have been made (Fig. 2). The edge of the bone plate in contact with the epiphysial cartilage appears to be calcified cartilage containing no cells or canaliculi (Fig. 3). The walls of vessels which traverse the bony plate have been seen to consist of a continuous membrane, and cells are sited at fairly regular intervals.

Zone of " resting " cells—Progressing towards the epiphysial growth cartilage, immediately under the bone plate there is a narrow zone of cartilage proper, consisting of a matrix of fine collagen fibrils and a ground substance, which cannot be identified by electron microscopy, but which corresponds to the polysaccharide identified by chemical methods. In the midst of this substance the first chondrocytes are found. They are the " resting " or " undifferentiated" cells of the text-books whose origin and destination are as yet uncertain; they are being investigated in this Centre at the present time. Close to the bone plate there are relatively

small cells (Fig. 3) appearing either singly or in pairs or more, facing each other by their flat side, as if they had been formed by cell division. In some sections farther down towards the columns more than two cells appear surrounded by a capsule. Sometimes this appearance suggests the commencement of a column of chondrocytes as seen in an oblique section, but particularly at the beginning of this segment their appearance is often very similar to that of the cells in the primitive cartilage. In many fields the tops of columns are found very close to the chondrocytes.

The epiphysial vessels reach as far as the beginning of this zone. After they have penetrated through the bone plate their walls no longer show a definite basement membrane, and it appears that the vessel contents are in direct contact with the cartilage matrix. At the level of the vessels the collagen fibrils have not yet acquired the constant parallel arrangement in the direction of the columns they take farther down between the columns, but in general the tendency to become parallel is apparent immediately below.

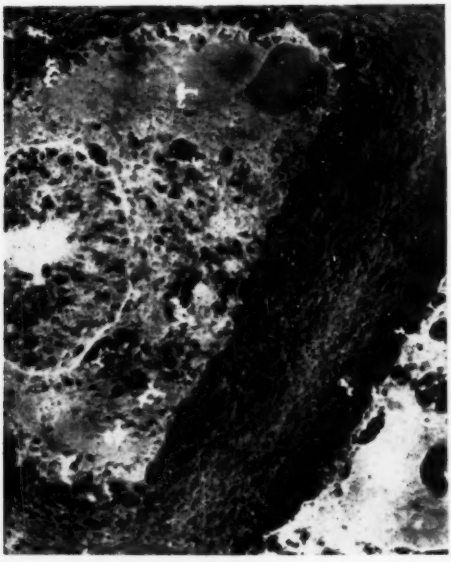

FIG. 8

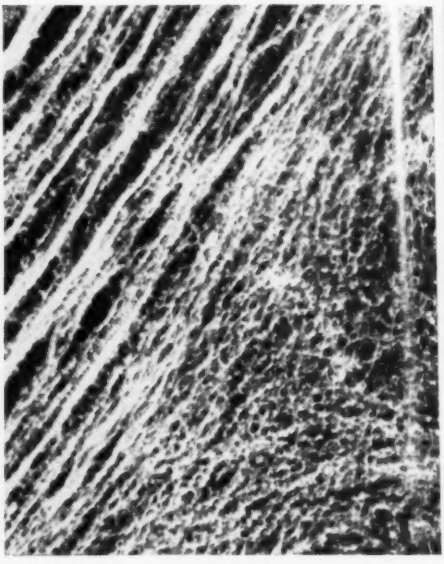

FIG. 9

Figure 8—Enlarging cell. (×3,675.) Figure 9—Matrix surrounding cells attached to orientated collagen. (×6,125.)

Proliferative zone—Immediately under the cartilaginous zone occupied by the isolated chondrocytes, the columns of proliferative cells appear. They are surrounded by the collagen fibrils already orientated parallel to the columns of cells, that is, normal to the surfaces, proximal and distal, of the growth cartilage (Fig. 4). These collagen fibrils are of the type with small diameter which do not readily show the 640 Å banding. It is indicated most clearly by the tendency of the surrounding ground substance to stick more firmly to portions of the fibrils separated by this interval.

It seems proper that the first part of the columnar arrangement which is occupied by flat cells should be called the proliferative zone. These cells are not often seen in mitosis, but the use of the electron microscope removes any doubt as to their activity. They are frequently observed in the stage immediately after division, with two nuclei in the same cell (Fig. 5), or with two cells still unseparated by matrix (Fig. 6), while others are found with the matrix in the process of forming a new intercellular septum (Fig. 7). There is a tendency for the

cells in a single column to be all in a similar state of division which is not necessarily equivalent to that seen in adjoining columns at the same level. Flat cells can frequently be found in one column while at the same level in the next column only partially enlarged cells are shown. The reason for this has already been indicated by the findings of Dr W. M. Rigal, working in this Department. In his tissue culture experiments the changes occurring in any given column tend to be synchronous. It seems that the stimulus to cell division is felt at once by the whole of a particular column.

At the end of the proliferative zone there are several cells which have begun to enlarge (Fig. 8) but the cells in this transition area appear to belong to the proliferative region and

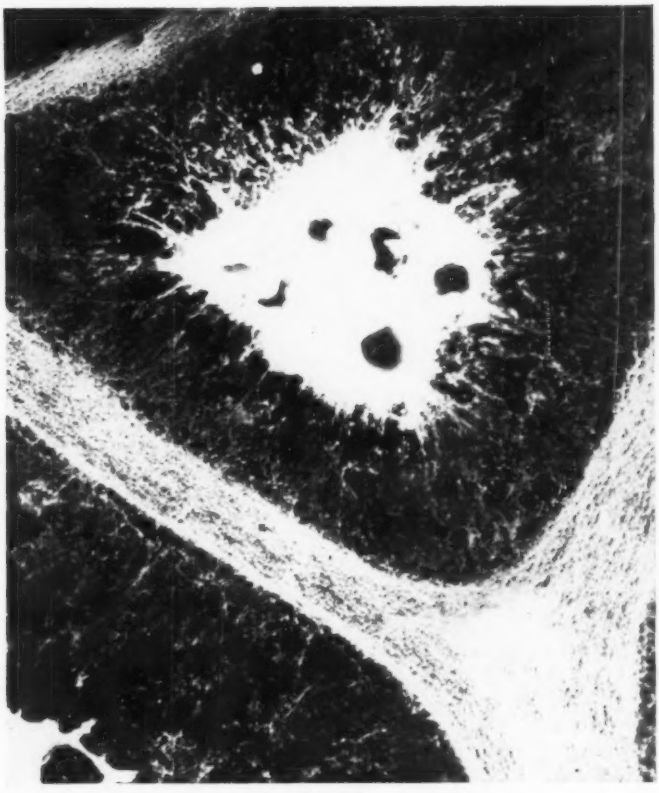

FIG. 10
Intercellular matrix in giant-cell zone. (×4,000.)

can sometimes be seen in the state which suggests recent division. The cells are surrounded by a mesh of parallel collagen fibrils to which the matrix of the intercellular systems is attached (Fig. 9).

Giant-cell zone—Progressing towards the metaphysis the cells rapidly increase in size, becoming more cuboid or spherical. The texture of the intercellular matrix changes, becoming more compact (Fig. 10), so that the boundary between cytoplasm and matrix is distinct.

At this level it is of particular interest to study the intercellular structure in the search for the first signs of calcification. This occurs first at the junction of an intercellular septum and the intercolumnar matrix.

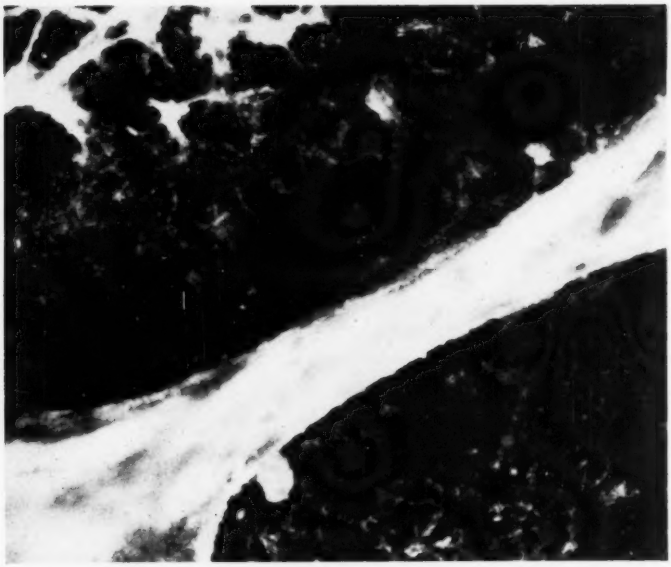

FIG. 11
Calcification of rabbit cartilage surrounding giant cell. (×8,420.)

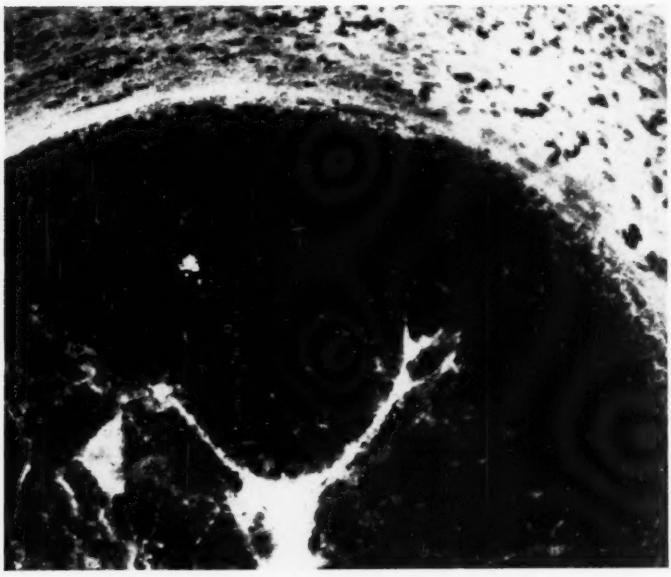

FIG. 12
Calcification of human cartilage surrounding giant cell. (×6,740.)

An interesting example of one of the minor differences between species is found here. Figure 11 and all the previous illustrations have been taken from the rabbit growth plate. Early calcification in a human growth plate is shown in Figure 12. The two specimens have been processed in a similar manner, but the appearance of the deposit is different in the two cases, that of the human growth plate being less uniform with a different crystalline structure.

As has been observed with the light microscope, the earliest appearance of the mineral deposit is found to occur at a distance of two to three cells from the end of the vascular loops which invade the column from their metaphysial side. As soon as the giant cell is completely surrounded by calcified cartilage it appears to start disintegrating; this corresponds to the zone of degeneration described in text-books. Probably because the calcified cartilage prevents the fixative from entering, well fixed cells of this type have not been observed.

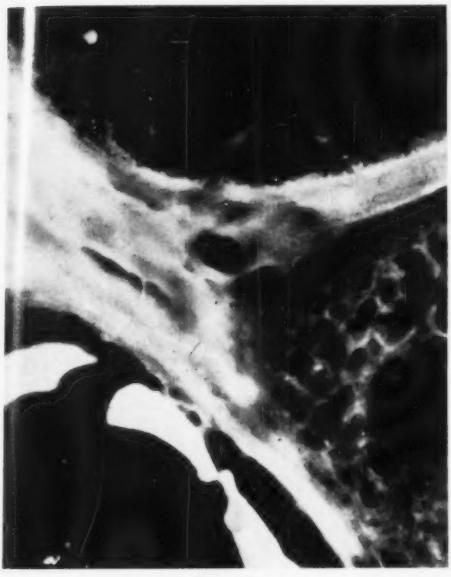

FIG. 13

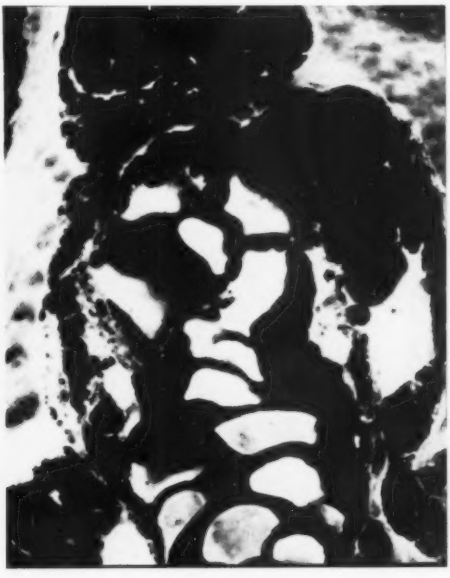

FIG 14

Figure 13—Capsule containing erythrocytes and a little barium sulphate suspension. (×7,000.) Figure 14—Endothelial cells in fixed capsule together with early vessel wall. (×2,800.)

Below the last degenerated cell appears a capsule filled with either erythrocytes, the injection material, or both (Fig. 13). Sometimes a few endothelial cells are seen against the sides of the capsule as if forming the end of the wall of the vascular loops described in Article I in this series (Fig. 14) but most commonly capsules are found not to contain any trace of vascular endothelium.

From now on towards the metaphysis the sections studied in the electron microscope depict the tissue which follows immediately under the growth cartilage proper. The vessels have a well-constituted wall, a continuous membrane on which endothelial cells are observed (Fig. 15). The calcified cartilage of the intercolumnar matrix spaces begins to be reinforced by layers of calcified osteoid (Fig. 16) and osteoblasts and soon osteocytes appear to constitute the first row of provisional trabeculae.

The calcified cartilage contains no cells and so the polysaccharide of its matrix soon disintegrates.

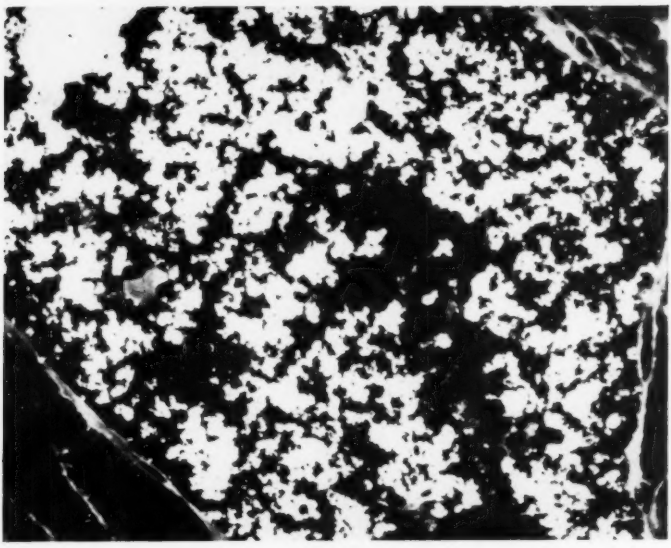

FIG. 15
Vessel wall at level of osteoid formation. (×3,200.)

FIG. 16
Calcified osteoid on calcified cartilage. (×6,000.)

Ossification is not seen to occur without the presence of the osteoblasts, and the highly specialised matrix of the ossifying zone must be attributed to them. Within this matrix are the canaliculi for processes to pass from the osteocytes and convey the necessary nourishment throughout the ossified area. This process of ossification will be considered in more detail elsewhere.

DISCUSSION

Previous studies of the growth cartilage by the electron microscope, particularly that of Scott and Pease (1956), have tended to concentrate on the internal structure of the chondrocytes, osteoblasts and osteoclasts; in our work we have been more concerned with the relationship between cell, matrix and vessel and the particular signs of cell activity found at every stage.

By the use of the electron microscope further light has been shed upon a number of points of interest which have already been studied by the light microscope. In particular, further information was desired about three areas of the epiphysial cartilage.

The layer immediately beneath the bone plate has been described as the resting, undifferentiated, or germinal zone. The electron microscope shows that there is a close connection between the vessels and the cartilaginous matrix. The vessels do not have clear cut walls in this region, but their contents are seen to be in contact with the surrounding matrix. The chondrocytes are frequently close to the vessels. The intercellular collagen first makes its appearance at this level, so that it seems that the cells of this zone must be responsible for preparing the matrix in which the cell columns will become established.

Thus, even if no reproductive function is assigned to these cells—a property about which this particular piece of work provides no evidence—the cells must have a high metabolic requirement for the production of the matrix. To provide the nourishment for these active cells there is the extensive vascular bed which forms an almost continuous ceiling over the zone. Only a narrow layer of the cartilage matrix interposed between the bone plate and the top of the cell column becomes calcified. In a work to be reported later the responsibility of the epiphysial vessels for the nourishment of the whole of the proliferative part of the cartilage has been established.

In view of the considerable activity of these chondrocytes at the top of the growth cartilage, it seems that the only appropriate name among the three that have been applied to them is that they belong to the germinal zone.

The electron microscope has brought confirmatory evidence for frequent mitosis through the whole length of the proliferative part of the column. As with light microscope observations, it is only on very rare occasions that cells are seen in the actual act of dividing, suggesting that this is an extremely rapid performance. Nevertheless, we have evidence of every stage in the process of division from the moment that mitosis has taken place.

The electron microscope has been useful in investigating the relationship between the metaphysial vessels, the last giant cells and the area of calcification. Whitehead (1960) has shown that changes occur in the matrix—sulphonation of the polysaccharide ground substance and an oxidising process—before calcification takes place. Direct observation with the electron microscope shows a changed appearance of the matrix in this region. Also it is seen that the earliest traces of calcification occur in that part of the altered matrix which is farthest removed from a cell. Any theory of calcification will have to take into account this fact. We have been able to confirm that calcification of the intercolumnar matrix follows the vascular progress with an impressive regularity keeping a constant distance between the limit of the calcification area and the vascular end.

It has been shown that the progress of the vascular loops within the rosary of giant cells is effected by the rupture of the partition between the capsules containing the hypertrophic cells. Until the vessel progresses into the space, the walls of the capsule are the only vascular walls. As the enchondral vascular cells progress towards the empty capsules, the thin membrane of the vessel wall is observed.

CONCLUSIONS

Throughout this work data have been gathered favouring the concept that the met physial vascular arrangement is primarily related to the process of enchondral ossification, nd has very limited, if any, responsibility for the nourishment of the growth cartilage.

The present evidence favours the suggestion that when the chondrocytes of the olumn have become too far separated from their source of nourishment (the epiphysial vesse) they and their surrounding matrix suffer changes which prepare them for the process of calcif tion. At least calcium and phosphate ions will be required for this to take place. The proximit of the vessel and also the fact that it is not isolated by a membrane at its very end suggests a ; ofuse interchange of fluids with the surrounding area.

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SOME OBSERVATIONS ON THE REACTION OF BONE AND TENDON AFTER TUNNELLING OF BONE AND INSERTION OF TENDON

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R. WALMSLEY, ST ANDREWS, SCOTLAND

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The suturing of severed tendons with recovery of function was a significant advance in surgical technique. One of the first descriptions was by Moinichen in 1665. That was followed later by the successful performance of a free tendon graft by Nisson (1770). Injuries to tendons have raised many technical problems, and the principles now influencing methods of treatment have evolved after considerable experimental work, notably by Bunnell (1944).

The main difficulty that has confronted those engaged in animal experiments has been the interpretation of the varied histological findings regarding the behaviour of the collagenous tissue of the tendon that is used as a free autogenous transplant. If the grafted tendon is inspected after a long time, it is seen to consist of normal tendon tissue and histologically is an accurate replica of the original tendon. Opinion is divided whether the new tendon is in reality the original graft, or whether it is a clever deception wrought by invading fibroblasts from adjacent host tissue. Likewise, there is no general agreement about the fate of the cells and tissues, other than those of the collagen itself, which are normally associated with tendon; among such non-collagenous elements are the endothelial cells of the blood vessels and also their muscle and elastic fibres. Peer (1955) has written a comprehensive historical review of the literature on this problem in which he has collated the experimental evidence of various workers.

The successful transplantation of autogenous animal fascial and tendon grafts has naturally stimulated the clinical application of similar techniques in man. The exploitation of tendon tissue as "living suture material" by Gallie (1913) has been used advantageously in reconstructive surgery for paralysed muscles. It was noted, however, that there was a gradual deterioration in function of tendon transplants into bone after initial apparent success, and the fault was attributed to the separation of the transplant from its bony anchorage. This was ascribed to ingrowth of areolar tissue into the bony groove to which the tendon was attached. Consequently, the adhesions attaching the tendon to bone became long and tenuous and unable to resist the tension caused by the pull of the muscle. Gallie and Le Mesurier (1921) therefore modified the technique by splitting and rawing the tendon ends before embedding them in bone. Bone chips were also packed into the groove and intermingled with the tendon ends before the periosteum was reconstituted.

Kernwein (1942) in a series of experiments transplanted the tendon of the extensor carpi radialis longus muscle in dogs. In some animals the sheaths were removed and the tendons were anchored in a bony tunnel after shredding the tendon ends which were intermingled with bone sand. A firm bony attachment was thus secured and the tendon transplant gradually became ossified and incorporated in the bone. It was found that the tensile strength of the tendon at the new insertion decreased for a time after the initial fixation and that the bone sand interspersed in the shredded tendon ends underwent aseptic necrosis. Kernwein considered that splitting the tendon insertion offered a greater area for invading fibroblasts and thus helped to consolidate the new anchorage and enhance the tensile strength. When an autogenous free graft is embedded in like tissue, its chances of survival are generally considered to be greater than if grafted to unlike tissue, although transplants of the latter type have

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remained viable for varying periods. Peer (1955) described the survival of tendon and ca tilage transplants buried in abdominal fat.

The synopsis of the above work is considered to be relevant because this communi ation is concerned with the histological changes that occur in a bone and an inserted tendor after it has been passed through a bony tunnel made with a drill. The experiments were perf rmed in adult rabbits and the changes that occur in tendon and bone were observed at int rvals over the greater part of a year.

METHODS AND MATERIALS

Eighteen adult rabbits of various weights were prepared for operation in the usual m nner and anaesthetised with intravenous " Nembutal." An incision was made over the l teral aspect of the right tibia that began about the junction of the uppermost and middle ıirds of the bone and a little posterior to its lateral margin. The incision extended beyond the nkle joint, and, curving below the lateral malleolus, was continued along the lateral border (the foot to the level of the metatarsals. When the skin flaps were retracted the tendons (the peroneal muscles, four in number, were identified and the peroneus secundus isolated. The tendon of this muscle is a flat, ribbon-shaped structure which is broad in comparison with its fellows. After the tendon had been followed as far distally as the ankle joint, the cov ring retinaculum was divided sufficiently to free the tendon. The tendon was thereafter t aced distally to its insertion, from which it was detached, and then wrapped in a sterile saline s wab. The lateral ligament of the ankle, which is a narrow, thin band running obliquely downv ards and forwards, was next sought; this ligament is attached above to the lateral malleolu and below to the lateral aspect of the calcaneum. After the ligament has been severed the arti ular surfaces of the ankle may be fully exposed by exerting slight pressure on the prox mal and distal bones of the joint. The lateral half of the ankle joint in the rabbit consists of the adjacent articular surfaces of the tibia and the calcaneum, whereas the talus occupies only the medial half of the joint where it is interposed between the tibia and the calcaneum.

A small thick electric twist drill was then used to make a bony tunnel which ran obliquely downwards from the lateral side of the tibia to its distal articular surface (Fig. 1). A second tunnel was thereafter drilled in the calcaneum beginning on its inferior surface close to its lateral aspect and passing upwards to pierce the articular surface in the ankle joint. The two tunnels were so orientated that the bony walls were strong enough to withstand an appropriate stress applied to the tendon after it had been threaded through the tunnels. In this procedure the distal end of the free tendon was ligated with a strong sterile thread and first passed through the tibial tunnel and then through the tunnel in the calcaneum so that it emerged from the inferior surface of that bone. The slack was then taken up. the tendon drawn taut and aligned over the lateral aspect of the ankle joint to be sutured back upon itself just above the upper end of the tibial tunnel. Two other cotton ligatures were tied at appropriate levels below the first ligature to reinforce the reconstructed lateral ligament. The wound was dusted with penicillin powder, and closed with interrupted sterile nylon sutures, and an occlusive Elastoplast dressing was applied.

The animals were killed at intervals between eight hours and 307 days after operation. and sections were prepared of the tunnelled bones and the associated tendons. The bones were so orientated during the sectioning that the tunnel and tendon in the bone were cut in their long axes. The microscopic sections were prepared in the usual manner and stained with haematoxylin and eosin.

OBSERVATIONS ON NORMAL TENDON

The microscopic structure of a mature tendon consists mainly of a dense mass of collagenous fibres that run parallel to the long axis of the tendon; between the fibres are fibrocytes which are likewise arranged in longitudinal rows (Fig. 2). The details of the blood vessels of a tendon are not considered in this paper, but it is noteworthy that tendons in

general are relatively avascular. Between the bundles of the collagenous fibres is a loose stroma which is sometimes referred to as the *endotenon*, and it is of significance that it contains fibroblasts—a feature to which reference will be made later; elastic fibres may also be

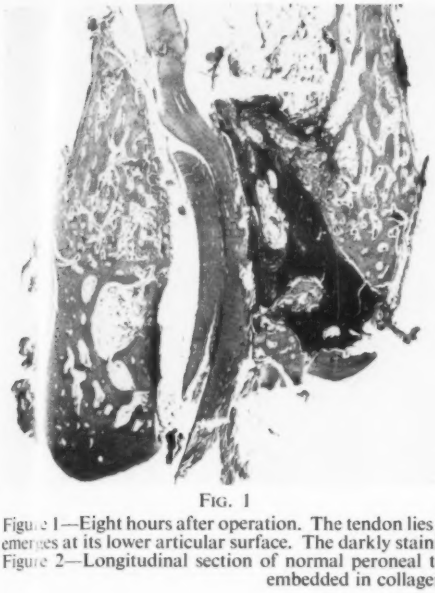

FIG. 1

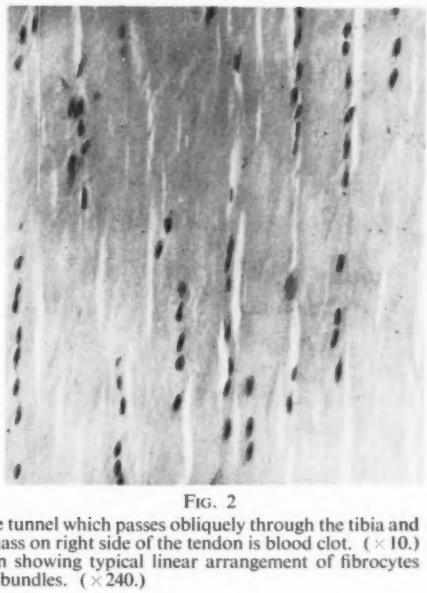

FIG. 2

Figure 1—Eight hours after operation. The tendon lies in the tunnel which passes obliquely through the tibia and emerges at its lower articular surface. The darkly staining mass on right side of the tendon is blood clot. (×10.)
Figure 2—Longitudinal section of normal peroneal tendon showing typical linear arrangement of fibrocytes embedded in collagenous bundles. (×240.)

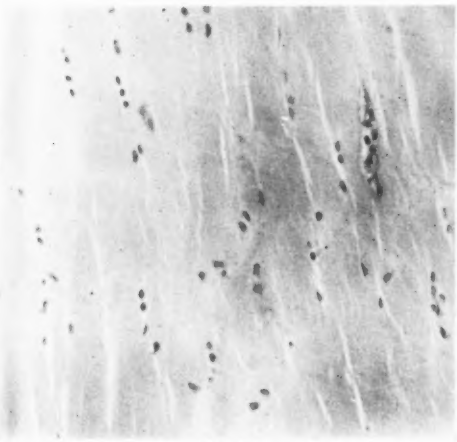

FIG. 3

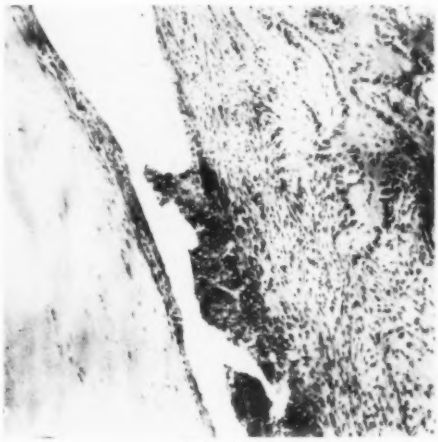

FIG. 4

Figure 3—Five days after operation: part of the tendon within the bony tunnel. It is characterised by the "ghost-like" appearance of the fibrocytes, and the collagenous tissue shows the initial stages of degeneration. (×240.) Figure 4—Five days after operation. The reticular tissue of the bone marrow adjacent to the tendon in the bony tunnel has undergone a cellular reaction. The tendon is on the left and the reticular tissue on the right. (×90.)

demonstrated in it. A mechanism which permits the gliding of a tendon in a lubricated channel is also provided in some places by the presence of a *true tendon sheath* which is often referred to as the *paratenon*. At its insertion into bone the fibrous tissue of a tendon also contains cartilage cells, and it therefore assumes the features of fibrocartilage.

Tendon is remarkable for its tensile strength: this is not surprising because collagenous or white fibrous tissue is better adapted than any other tissue to withstand tensile forces. Despite the apparent simplicity in the structure of a tendon the changes that occur in it after it has been passed through a bony tunnel are still controversial, and that is one of the reasons why the experiments described in this paper were undertaken.

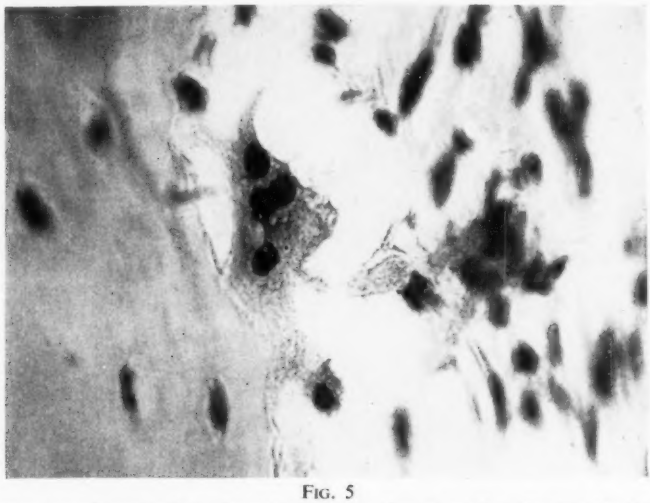

FIG. 5

Ten days after operation. From the tenth day after the making of a tunnel in the bone and the implantation of a tendon in it, osteoclasts become conspicuous in the bone adjacent to the tunnel. One osteoclast is seen adjacent to bone on the left and another is out of focus on the right. (×750.)

OBSERVATIONS IN TENDONS AFTER OPERATION

Eight hours after operation the transplanted *peroneus secundus* tendon may be seen lying in the bony tunnel in the tibia and emerging at its articular surface (Fig. 1). The wall of the tunnel is fairly smooth and the tendon lies freely within it. Because the drill is thicker than the tendon there are considerable intervals between the tendon and the wall of the tunnel, but these spaces may be obliterated in places either by the tendon lying against the wall or by traumatic haematomata. The effect of the drilling is also obvious on the articular cartilage, which is partially detached and fragmented. The collagenous tissue of the tendon is apparently normal at this short interval after operation.

Two days after operation the fibrocytes in the tendon are beginning to undergo a degenerative change, as indicated by their failure to stain in the normal way, and the collagenous fibres likewise are less well defined and stain faintly compared with those of normal tendon. The reticular tissue of the bone marrow remains essentially normal, but scattered along the wall of the tunnel are groups of round cells and polymorphonuclear leucocytes. Osteoclasts, which will in later stages be plentiful, have not as yet become conspicuous at this early date after operation.

Five days after operation (Fig. 3) there are further degenerative changes in the tendon, notably a decrease in the number of fibrocytes; most of the nuclei that persist are faintly stained and have a " ghost-like " appearance. The collagenous fibres simultaneously undergo " myxomatous " degeneration and form an amorphous poorly staining matrix. The tendon still lies freely within the tunnel, the wall of which remains remarkably smooth with small focal haemorrhages and groups of polymorphonuclear leucocytes and round cells scattered irregularly in it. The reticular tissue of the adjacent bone marrow has undergone a marked

FIG. 6

FIG. 7

Figure 6—Fifteen days after operation. After this time the fibroblasts stream out from the cavernous spaces of the bone into the tunnel and invade the periphery of the enclosed tendon. (×10.) Figure 7—Twenty-eight days after operation. There is a close connection between the tendon and the reticular tissue of the cavernous spaces. A trabecula of the bone on the left of the tendon presents a smooth surface to the tunnel. (×10.)

FIG. 8

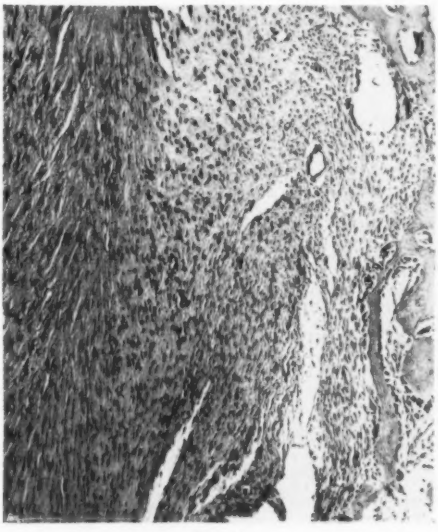

FIG. 9

Figure 8—Five weeks after operation. The close connection of the tendon and the reticular tissue of the cavernous spaces is again evident in this specimen. (×10.) Figure 9—Same specimen as in Figure 8. The close connection between the reticular tissue on the right and the tendon on the left is evident. (×60.)

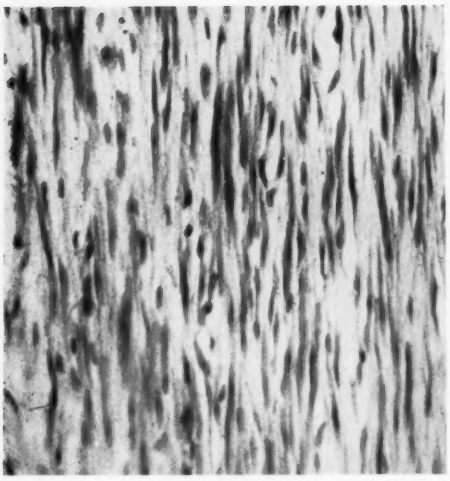

FIG. 10

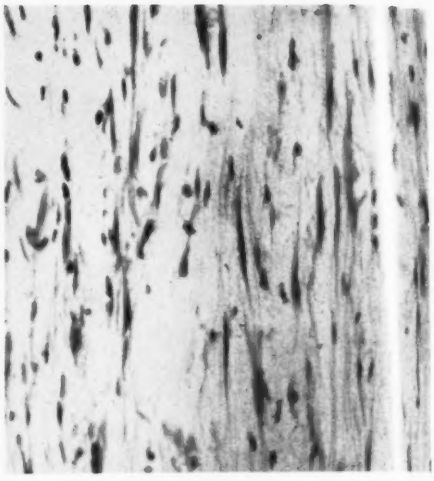

FIG. 11

Figure 10—Five weeks after operation. The peripheral part of the tendon at this stage is extremely cellular and shows the numerous fibroblasts elongated in the long axis of the tendon. (×240). Figure 11—Five weeks after operation: the central part of the same tendon as seen in Figures 8, 9 and 10, and especially to be compared with Figure 10. The fibroblasts in it are much scarcer and "ghosts" of some of the original fibrocytes are visible. (×240.)

FIG. 12

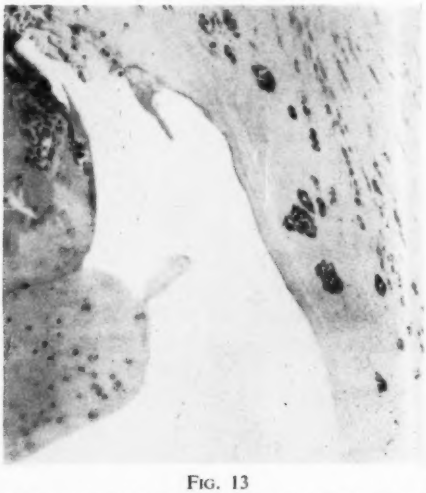

FIG. 13

Figure 12—Seven and a half weeks after operation: the close relationship between the "new tendon" and the reticular tissue of the marrow. (×10.) Figure 13—Seven and a half weeks after operation. The tendon is on the right and the lower articular surface of the tibia on the left. In the superficial part of the tendon are seen clusters of cartilage cells. (×100.)

cellular reaction and in it numerous fibroblasts may be identified (Fig. 4). The stimulus for this cellular reaction in the adjacent cavernous spaces is, it is postulated, due to the presence of an unlike tissue—namely tendon—having been embedded in the medullary cavity of the tibia, although it may partly be a reaction to the drilling.

Ten days after operation osteoclasts became a dominant feature in the bone adjacent to the tunnel (Fig. 5) and they continue to be so during the following four months. Over this period the bone is actively remodelled and it is considered that osteoclasts are associated with this as also are the osteoblasts, which are very prevalent during the same period.

Throughout the second and third weeks the changes that have been described in the tendon within the bone five days after operation progress. The most apparent feature is the increase in the number of fibroblasts, which stream out from the cavernous spaces of the bone into the tunnel (Fig. 8) and invade the periphery of the tendon within it. As time passes there is an increasing close connection between the periphery of the tendon and the reticular tissue

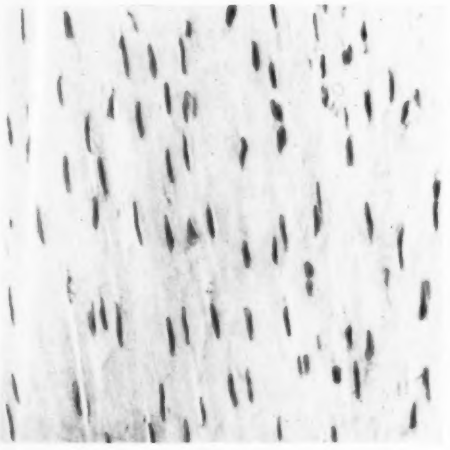

FIG. 14

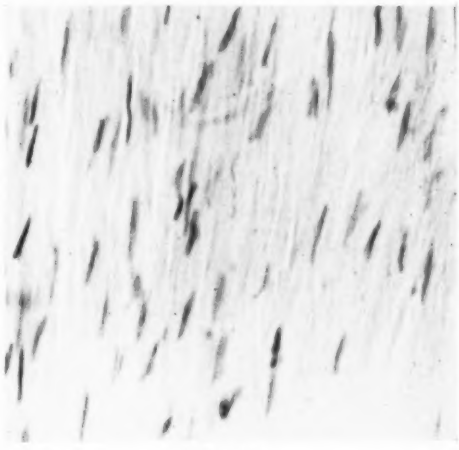

FIG. 15

Figure 14—Section 307 days after operation: the central part of the " new tendon "; the fibroblasts are seen to be less numerous, shorter and more deeply stained than in Figure 10. (×240.) Figure 15—Tendon in bony tunnel 736 days after operation. The fibroblasts are fewer than in the 307-days specimen and some of them are assuming the form of fibrocytes. (×240.)

of the bone marrow spaces; this is evident in the photograph of an appropriate section twenty-eight days after operation (Fig. 7). Where such connections exist in the early stages after operation, the cellular activity in the bone marrow spaces is especially prominent and in these regions the reticular tissue is alive with cells that invade the sides of the tendon. The invading cells are disposed in ill-defined whorled masses, but as they are traced into the substance of the new tendon they become orientated parallel to its long axis. Although the fibroblasts in the reticular tissue predominate, various other types of cells, many of them round cells, are obvious in every field. It is considered that the periphery of the tendon is the region of greatest significance in the early stages because it is postulated that there is a gradual replacement of the tendon in the tunnel by the invading cells of the reticular tissue. Coincident with the cellular invasion of the peripheral part of the tendon there is a progressive degenerative change in its central core which affects both the collagenous fibres and the fibrocytes.

Five weeks after implantation in the bony tunnel, the periphery of the tendon remains connected throughout a considerable part of its length with the reticular tissue of the marrow (Fig. 8), the cells of which continue to proliferate and are very obvious in appropriate sections

(Fig. 9), This cuff of tendon tissue, which is characteristic at this stage, contains much young collagenous tissue disseminated with innumerable active, proliferating fibroblasts (Fig. 10). The fibroblasts, moreover, continue to migrate towards the central core of the tendon which is, however, still readily identified because of the degenerative processes which are occurring in both its ground substance and fibrocytes (Fig. 11). This degenerative core is considered to be the last part of the original tendon to persist, and although it may contain a few fibroblasts it is relatively acellular compared with the periphery of the tendon.

These histological appearances, illustrating the gradual replacement of the tendon within the tunnel by cells from the bone marrow, continue in later stages, and an example given and a half weeks after operation is seen in Figure 12. The continuity of the upper part of the tendon with dense reticular tissue is clearly demonstrated, and the fibroblastic replacement of the central core is more advanced. As the tendon is traced distally, however, it becomes less cellular, especially at the level of the articular surface of the tibia, with which it is not fused. Here, moreover, clumps of cartilage cells may be identified in the actual tendon tissues; this is regarded as an interesting finding (Fig. 13).

The fibroblasts derived from the reticular tissue of the medullary cavity eventually invade the central core of the tendon, and, after being associated with the laying down of new collagenous tissue, or ground substance, the intra-canalicular structure becomes less cellular. Such is apparent in sections made 307 days after operation (Fig. 14). The intra-canalicular structure at this stage closely resembles that of a normal tendon. The cells in the newly created tendon are more numerous, and rather longer, than the fibrocytes shown in Figure 2, and consequently are still regarded as fibroblasts rather than as the fibrocytes of a normal tendon.

DISCUSSION

The behaviour of tendon tissue, when employed as a free autogenous transplant, has proved highly controversial. Broadly there are two main views, the one affirming that the parenchymal cells of such grafts are capable of survival and of participation in the process of repair (Mason and Allen 1941, Peer 1955), the other maintaining that degenerative changes are inevitable, and that a process of replacement by invading cells from surrounding host tissues must necessarily occur before healing is complete (Skoog and Persson 1954). Regeneration of the new tendon has also been attributed primarily by others to activity by the tendon sheaths enveloping the tendon stumps in the belief that the tendon itself takes no active part in the regeneration (Adams 1860).

Naturally a diversity of views regarding this problem, based on interpretations of stained sections, would not be unexpected from those experimenting with different species, but conflicting theories are also encountered among those working under similar conditions. Peer emphasised the difficulty of differentiating stromal fibroblasts—that is, tenoblasts between the tendon bundles—from invading fibroblasts derived from adjacent host tissue. He further commented on the general reluctance to make specific pronouncements on the ultimate fate of various cellular components of transplanted tissue, such as the collagenous and elastic fibres, the fibroblasts in the stroma or endotenon, and the endothelial cells lining the capillary vessels.

Reviewing our histological findings, we postulate that the sequence of events is as follows. First, the transplanted tendon in the bony tunnel undergoes a degenerative change which is well established by the fifth day. Simultaneously, there is a proliferation of fibroblasts in the adjacent reticular tissue of the bone marrow lining the tunnel which gradually becomes more marked, and these cells migrate towards the periphery of the tendon and invade it. By the twenty-eighth day the invasion of the transplanted tendon by the fibroblasts is clearly demonstrated. Sections taken later show that the wall of the tunnel and the edges of the tendon gradually coalesce, and a close connection between them is established by the thirty-eighth day. The invading cells migrate steadily towards the central "core" of the tendon

and this " core " (as long as it persists) is easily identified on account of the degenerative changes affecting its parenchymal cells; it is thus surrounded by a cuff while the replacement process is in progress. This central " core " is the last area to be overrun by the invading cells.

By the fifty-second day the continuity of the proximal part of the tendon with the adjacent, dense, reticular tissue of the marrow is an obvious feature, and the fibroblastic infiltration of the central tendon " core " continues. Interesting at this stage are the clumps of cartilage cells within the new tendon opposite the articular cartilage of the distal end of the tibia where it remains separate from the cartilage. It is considered that this part of the tendon is subjected to pressure which accounts for the presence of cartilage cells, and this assumption is in keeping with the findings of Glücksmann (1939) who in his *in vitro* experiments found that pressure causes cartilage formation in perichondrium and periosteum. By the 307th day, sections indicate that activity both within the transplanted tendon and also in the part of the medullary cavity of the tibia bounding the tunnel is no longer so intense. The tunnel does not possess well defined walls and the periphery of the tendon is continuous with the surrounding reticular tissue. Comparison of the tendon parenchyma in the tunnel at 307 days with that of normal tendon tissue shows a resemblance, the main difference being that fibroblasts have replaced fibrocytes. Later still the histological appearance of the transplanted tendon would, it is believed, have been identical with that of normal tissue. Good reason for making such a deduction is that in a specimen prepared 736 days after operation, in which the tendon had been passed obliquely through the tibia, the histological appearance of this tendon was even more akin to that of normal tendon (Fig. 15). This specimen, however, belongs to a different series of experiments because the bony tunnel did not pass through the articular cartilage of the distal end of the tibia.

The conditions of this experiment are not quite the same as those encountered when a free, autogenous tendon transplant is performed. First, the transplanted tendon in our experiments, although severed from its insertion, still remained attached at the musculotendinous junction to its parent muscle and presumably retained some of its blood supply. Tendon is usually nourished partly by vessels which enter its substance either from the muscle belly or from the bony attachment. Secondly, the transplanted tendon was embedded in unlike tissue—the tunnel fashioned in the medullary cavity of the tibia—and could therefore be regarded as filling the role of an " autogenous foreign body." Consequently, it is considered that the tendon contributed, together with the drilling of the tunnel, in providing the stimulus for the ensuing cellular reaction in the surrounding host marrow tissue.

The remarkable cellular response in the reticular tissue of the bony cavernous spaces adjacent to the tunnel is regarded as important. The source of the invading host cells postulates certain parent cells which are capable of multiplying and differentiating rapidly in response to a specific stimulus or stimuli. It is interesting that these parent cells ultimately replace almost perfectly a different form of connective tissue, namely tendon.

Our observations accord with the statement of Maximow and Bloom (1952) that the original mesenchymal potencies are retained by cells scattered in the loose connective tissue along the blood vessels and by the primitive reticular cells of the haemopoietic tissues. It is postulated that it is from the primitive reticular cells that the fibroblasts which are concerned in the formation of the " new " tendon are derived. It is considered that, once differentiation has occurred, the daughter cells begin to lose their potential to revert to any other type of connective tissue cell, and even to cease proliferating when maturity has been reached.

Reference has been made to the presence of numerous osteoblasts and osteoclasts between the tenth day and the fourth month after the drilling of the bone and the insertion of the tendon. Drilling must disintegrate the bony trabeculae and form much bone dust. The remodelling process in a bone so tunnelled is very considerable, and may influence the presence of the osteoclasts. As this paper is primarily concerned with the regeneration of the tendon the full consideration of the reaction of the bone is deferred to a later paper.

SUMMARY

1. A series of experiments on adult rabbits was carried out in which a tendon was transpl nted and embedded in a bony tunnel and traversed a joint after the manner of a tenodesis.
2. Histological observations were made on the reaction of surrounding bone and tend n at intervals over a period of 307 days.
3. The findings suggest that the buried tendon undergoes a process of progressive degener: ion, and that host cells issuing from the adjacent bone marrow infiltrate and ultimately repl. :e it by new tendon tissue.
4. The invading cells are believed to be derived, as a result of the provocative stimuli pro· ded by the experiment, from primitive reticular cells of the haemopoietic tissue.
5. The tunnelled bone undergoes considerable remodelling and associated with this i the presence of a considerable number of osteoblasts and osteoclasts.

The authors would like to take this opportunity of according their sincere thanks to the Nuffield Foun tion Rheumatism Committee for the grant made some years ago which allowed them to purchase selected r: bits and also to house them under perfect conditions. We also extend our thanks to Mr James Brown f the photographs and to Mr Ronald Stuart for the preparation of the microscopic sections.

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MUSEUM PAGES

III. Spina Bifida and Epiphysial Displacement

CAMPBELL GOLDING, LONDON, ENGLAND

The orthopaedic problems that occur in spina bifida are the result of the neurological dis rder which causes partial paralysis and sensory disturbance. The dysplasia of bones and joi ts during growth and the development of Charcot's joints are attributed to these factors. Th occurrence of fractures with excessive callus, and the peculiar lesions near the knee which are the subject of this report, are ascribed to the same causes, without however a clear un erstanding of the mechanism which produces the n.

A patient born with spina bifida may have no mal hip joints, but is prone to progressive dy plasia of the sockets, coxa valga and bilateral dis ocation from muscular imbalance (Milch and Green 1936, Nathanson and Lewitan 1944, Müller 1939).

The various deformities of the feet, of which equinovarus is the commonest, are not radiological problems, but the impairment of sensation, which is both exteroceptive and proprioceptive, is followed by ulcers and neuropathic disorganisation of joints. The lesions of the phalanges and metatarsals may resemble the most severe deformities of leprosy (Camera 1955) (Fig. 1), and any large series of cases also contains a few typical Charcot's joints, the ankle being the usual site.

FIG. 1
Deformity of the forefoot in a patient with perforating ulcers from spina bifida.

The most complete description of the orthopaedic aspects of spina bifida is that of Carr (1956). Among the patients that he reported was one who was radiographed at this hospital (Royal National Orthopaedic Hospital) (Mr K. I. Nissen's case). The lesion involved the epiphysis and metaphysis of the tibia and was basically a displaced epiphysis. The epiphysial line was much wider than normal; the epiphysis, metaphysis and upper half of the shaft were sclerosed; there was some loose debris in soft tissues; and the appearance suggested a neurotrophic disorder of a Charcot type (Fig. 2). The metaphysis of the opposite tibia was dense but there was no displacement (Fig. 4). It was known that the patient had spina bifida. Biopsy was not done. The patient was treated conservatively with almost complete resolution (Fig. 3).

Only two cases which resembled this have been traced in the literature (Gillies and Hartung 1938). These were described as fractures of the tibia, and in each case a fracture was present 1·5 centimetres below the epiphysial line. These lesions bore some resemblance to a sarcoma and to syphilis. A biopsy excluded sarcoma.

FIG. 2

FIG. 3

FIG. 4

The epiphysis of the left tibia (Fig. 2) is displaced. The epiphysial line is wide and irregular; there is sclerosis and loose bone producing the appearance of a neurotrophic disorder. After conservative treatment for six months the condition had resolved almost completely (Fig. 3). The right knee showed sclerosis of the metaphysis (Fig. 4). There was no history of injury. (Mr K. I. Nissen's case.)

FIG. 5

FIG. 6

Figure 5—A case from the Museum. The appearance is much the same as in Figure 2 but there is some resemblance also to sarcoma. Figure 6—Another case in a boy of fifteen. He was known to have had subacute osteomyelitis of the first metatarsal bone in 1953: this was associated with a trophic ulcer. There was no history of injury in 1958 when he was admitted for swelling of the knee. (Mr G. Lloyd-Roberts's case.)

There are now three examples of this peculiar lesion at the knee and one of the lower tibial epiphysis in the Museum of the Institute of Orthopaedics. None of the patients had suffered local injury. In one patient the femoral epiphysis was affected (Fig. 5); the changes closely resembled those in the case illustrated in Figure 2. In another the tibial epiphysial line was involved, with excessive callus formation below the lesion (Fig. 6).

FIG. 7

Another case with involvement of the ankle. The lesion is comparable to those near the knee. There was no history of injury. (Mr D. M. Brooks's case.)

It was once thought that this lesion was confined to the knee; but the case of a patient recently admitted under Mr D. M. Brooks (Fig. 7) shows that the same condition may be found near the ankle, and doubtless any epiphysis or metaphysis may be involved.

These lesions are worth reporting because they may resemble sarcomata or Charcot's arthropathy. Radiographs of the lumbar spine will indicate the true diagnosis and eliminate the need for biopsy. Mr Nissen's case shows that conservative treatment may be successful.

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FINGERS, COMPENSATION AND KING CANUTE*

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The search for the origin of ideas is a fascinating exercise; but it can lead one far into the forests of history. We started with digital nomenclature and modern schedules of compensation for injury; we rapidly got to King Canute, but that was by no means the end of the story.

During August 1959 in Copenhagen one of us (N. C.) gave a lecture upon "The Hand" and in the course of it referred to the ancient nomenclature of the digits which the other (A. B.) knew from the laws of Canute. All that most of us in Britain know about Cnut is that he was a Danish King of England from 1016 to 1035 and that he rebuked the flattery of his courtiers by showing that the advancing tides paid no heed to his commands. Some may even know that his bones are preserved in Winchester Cathedral. King Canute was also King of Denmark and of Norway, and for all three countries he drew up a code of laws. The fact that in them he laid down certain principles of compensation for injuries is of special interest when, in modern times, we regard the schedules of disability published by the Welfare State as a sign of social advancement.

The naming of fingers was well discussed by Wood Jones, first in his classical work on *The Principles of Anatomy as seen in the Hand*[1] and again in his delightful essays on *Life and Living*.[2] In the latter, on *The Mammalian Toilet and its Biological Implications*, he gave an interesting account of the anatomical adaptations which facilitate such things as cleaning the teeth and keeping one's fur tidy. In dealing with the problem of removing wax from the ear he wrote:

> "Whatever may be the mechanism of freeing wax from the depths of the ear, there is no doubt that its ultimate removal is, in man, effected by the nail of the little finger. So obvious is the office of the little finger in this connection that for centuries the fifth digit of the hand has been known to the learned by the name *auricularis*. Today we term it minimus, but to my mind, though this name may be considered more polite, it lacks the distinction of assigning a definite function, however humble, to this digit.
>
> "In this matter of digital nomenclature we may take Diemerbroeck (1609–74) as our guide. Of the digits he says: 'The first, which is the thickest, and equals all the rest for strength, is called pollex or the thumb. The second is the forefinger from the use, called the index, or demonstratur, the pointer because it is used in the demonstration of things. The third or middle-finger is called impudicus, famosus, and obscoenus, the obscene and infamous, because it is usually held forth at men pointed at for infamy, and in derision. The fourth, the ring-finger, or annularis and medicus, the physician's finger; because that persons formerly admitted doctors of physic were wont to wear a gold ring upon that finger. The fifth, called the little-finger, in Latin auricularis, or the ear-finger, for that men generally pick their ears with it.'"
>
> Wood Jones goes on. "It may perhaps be doubted if this explanation of the name 'obscoenus' for the third digit is correct. We all know of the degradation that results from being pointed at with the finger of scorn, but I have a fancy that this is not the origin of that very peculiar name for the middle, or longest digit of the hand. Do we in fact point the third finger at anyone as a sign of contempt or scorn? I think that in such a case the index finger would be employed, and I am very sure that the name 'obscoenus' was given to the third finger for an altogether different, but extremely obvious, reason. As for auricularis, he is clear and direct. There is no gainsaying Diemerbroeck's explanation of the name."

It is clear from a study of King Canute's laws that such names for the fingers are very ancient. The laws were written in medieval Latin and in Anglo-Saxon, a modern version, based upon the manuscript in the Colbert Library at Paris, was printed in Copenhagen in 1826[3] and the introduction to them states: "Hic incipiunt leges Cnuti, regis Anglorum, Danorum

* Based upon a paper presented to the Combined Hand Surgery Clubs at the Royal College of Surgeons of England on November 28, 1959.

et Novorum, viri justissimi et probattisimi." There is of course in the document much that is of no special interest to us (one being that he laid the foundation of the jury system). Canute did, however, state the principles of compensation for particular injuries, notably to the hand, for the digits of which he gave various names. The currency used was the solido or schilling, which as far as we can discover was a coin of considerable value. There is reason to believe that the solido valuations can be interpreted as percentages, because 100 solidos were awarded in total paralysis after a broken neck, and Trevelyan[4] remarks that 00 schillings were paid if a man was slain. In Canute's laws, for the loss of the pollex the compensation is valued at 30 solidos. For the "Secundus digitus nominatur index sive demonstratorius" the amount was 15 solidos. For the "tertius digitus qui nominatur impudicus" it was 12 solidos; for the "quartus annularis" 18; and for the "quintus auricularis" 9. Compared with the British Ministry of Pensions[5] schedule the resemblance is striking, for there the losses respectively are reckoned at: for the thumb 30 per cent; for the index finger 14 per cent; for the middle finger 12 per cent; for the ring finger 7 per cent; and for the little finger 7 per cent.

COMPENSATION FOR AMPUTATIONS

Alfred and Canute	Solidos	Ministry of Pensions	Per cent
Pollex	30	Thumb	30
Demonstratorius	15	Index	14
Impudicus	12	Middle	12
Annularis	18	Ring	7
Auricularis	9	Little	7

We see therefore that in Canute's time the overwhelming importance of the thumb was fully recognised. This point is emphasised when we find that for the fracture of one arm 15 solidos were paid, but if both arms were fractured 30 solidos. Loss of the thumb was equivalent to fractures of both arms, and fractures were certainly very serious in those days.

Canute was a great king, for, as Trevelyan[4] states, "had he lived until sixty instead of dying at forty, he might have left a more permanent mark on the world's affairs. He was on the way to found a Nordic empire astride the North Sea with Scandinavia for one pillar and England for the other. Sea power would have been its cement and its masterspirit." Although his laws contain much that was original, a great deal was based upon earlier Anglo-Saxon models; particularly this matter of compensation for mutilations, which we find is taken almost verbatim from the laws of King Alfred the Great of Wessex (*c.* 848–900).[6] But the story does not end there, because we find that Aethelbert, the first Christian Anglo-Danish king of Kent, who died in 616, laid down the same principles of compensation though in somewhat more primitive form.[7] Aethelbert described the index finger as the "shooting finger." The question now is whether he was the originator of the idea of scheduled compensation for mutilation. The answer must be in the negative, for in the laws of the Salic-Franks (the northern tribes of the Merovingian Empire) dating from some time between 507 and 511,[8] we find it laid down, for example, that if a hand or foot is cut off 100 solidos must be paid; for a thumb 50 solidos; and for the index finger 35 solidos. This finger in the Salic laws was named the "sagittatur"—the finger that shoots the arrow, a point that lends support to the view that it was from this source that Aethelbert got his idea, a probability which is reinforced by the knowledge that he married a Christian princess, the daughter of the Frankish king Charibert of Paris. It was she[4,9] who persuaded him to accept Christianity when Augustine landed in Kent in 597. Was it not probable that she also brought him some of the civilised ideas of her Frankish ancestors?

And that is almost the end of our search: it only remains to note that we have not been able to obtain any evidence that such compensation schedules are to be found in Roman law.

Perhaps, therefore, we should revise somewhat our opinions upon the darkness of the ages in which our Nordic ancestors lived.

NAMES OF THE FINGERS

Modern English		Alfred's Anglo-Saxon
THUMB	Pollex	DUMA
INDEX	Forefinger, salutatorius, demonstratorius, shooting, sagittatur	SCYTHE FINGER
MIDDLE	Medius, famosus, impudicus, obscoenus	MIDLESTAFINGER
RING	Annularis, medicus	GOLDFINGER
LITTLE	Minimus, auricularis	LYTLAFINGER

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PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

ROYAL COLLEGE OF SURGEONS OF ENGLAND

ROBERT JONES LECTURE

At the Royal College of Surgeons of England, on January 14, 1960, Sir Walter Mercer gave the Robert Jones Lecture for 1959, taking as his subject "Some Edinburgh Pioneers in Orthopaedic Surgery." Sir Walter thanked the President and Council of the Royal College of Surgeons of England for the special privilege and honour it was to him to be chosen to speak on their behalf and pay a tribute to one of the great men—indeed the greatest—in orthopaedic surgery. He referred to his early memories of Sir Robert Jones when the latter visited the Edinburgh War Hospital at Bangour after the first world war.

He found it interesting, in looking up the records in the Edinburgh College of Surgeons, to discover that after taking his M.R.C.P. in England in 1878, Sir Robert later took his Triple Qualification Licence in Edinburgh and in 1889 his Fellowship of the Edinburgh College, and that particular College on the advice of his uncle, H. O. Thomas, who, of course, was an old student of the University of Edinburgh. In his application he described himself as—Robert Jones, M.R.C.P.Eng., 1878, L.R.C.P. Edinburgh, 1884, Senior Assistant Surgeon, Stanley Hospital and Port Sanitary Officer for the Government of the United States. He was proposed by John Sibley Hicks. Hicks was medical officer on liners between Liverpool and America for a time and then for forty years was in practice in Erskine Street in Liverpool. He was Vice-President of both the Liverpool Field Naturalists Club and the Liverpool Literary and Philosophical Club.

Sir Walter said that it was not difficult, therefore, to trace the relationship between Sir Robert and Hicks since they must have met in their work on American ships, and in any case Hicks was a member of the Literary Society of which Sir Robert, writing in 1920, said, "Some thirty years ago three or four of us founded a little society in Liverpool which is now called the Liverpool Medico-Literary Society."

Jones's application for Fellowship was seconded by J. Halliday Croom, who later became the distinguished Professor of Obstetrics of Edinburgh University and was knighted. According to the Croom family Sir Robert Jones's only possible connection with Sir Halliday Croom was that the latter spent all his vacations in the Lake District and no doubt met Sir Robert there.

In 1909 the Royal College of Surgeons of Edinburgh awarded him the Liston Victoria Jubilee prize for the greatest benefit done to practical surgery by any Fellow during the preceding quadrennial period. "Mr Robert Jones," it was stated, "is one of the greatest living surgeons, and the advances he has made in orthopaedic surgery in the past few years have been very great."

After their first meeting Sir Walter saw him frequently and came, like all his disciples, to love the man. From his contacts with him, which, of course, were never very close, he was always impressed with Sir Robert's great energy and industry, his capacity for affection, and his power of making others love him. His genius ranked him with the great observers of nature—wholesome, finely poised, of simple living and high thinking.

The faithful study of nature seemed to lead to a certain calm happiness and contentment. The eagerness and joy of observation, the joy of discovering the causes of things, seemed to transcend all else be the quest within the closed walls of the dissecting room or in the operation theatre.

Sir Walter went on: "In studying this great life, while we must admire his genius and all he accomplished, let us dwell even longer on the beauty and strength of his character, the simplicity of his whole nature, the humbleness of this great man.

"If one attempts further to analyse the factors which specially contributed to his greatness one might think in the first place of an intellect of quite exceptional calibre. Perhaps he had not the imaginative creative genius of Lister, nor yet the broad culture and philosophic genius of Osler, but only in the sense that he was overwhelmingly a man of action, a rationalist rather than a theorist.

"The second factor in Sir Robert's success was that complex quality, as difficult to define as is character, which we call personality and of which in this instance the chief components were an intense vitality and an ardent enthusiasm. He left a most vivid and lasting impression on his pupils. He had

an animation and an enthusiasm which no amount of fatigue seemed able to stale, and it was thout doubt these qualities which made him so supremely successful in the sick room. As wel as his knowledge, his patients knew that to all, rich and poor, he would bring with gentle hands and ender heart the best that was known of our art.

" Another factor in Sir Robert's success, and perhaps the most important, was his capa ty for intense concentration and unremitting hard work. This was the solid foundation on which the lliant superstructure was built and without which, despite exceptional gifts of intellect and persona , his achievement would not have been possible.

" His interest in his vocation amounted to an all-absorbing passion so that it seemed to c ne to him naturally ' to scorn delights and live laborious days.'

" No one did more than he to establish orthopaedic surgery as a science as well as an art, it the debt we owe him is to be measured not only by his contribution to our knowledge but also, a even more, by the example he gave us.

" All of us in Edinburgh have a deep sense of pride that Sir Robert chose to take his Fell vship at the Edinburgh College. In thus associating himself with Edinburgh he joined there a table group of pioneers in orthopaedic surgery and, indeed, it may well be that the traditions o these orthopaedic pioneers may have been the reason H. O. Thomas sent him to Edinburgh for the igher degree. To some of these men I now propose briefly to refer."

Sir Walter thereafter spoke of Edinburgh's contribution to orthopaedic surgery and refe ed to many of the early pioneers in the speciality. He spoke of Alexander Monro, the Bells, Liston Syme and Lister. A master anatomist, Goodsir, described much that was new in the knee join and Annandale performed the first deliberate and planned operation for the relief of the in ernal derangement of the knee caused by a displaced semilunar cartilage.

He concluded: " It is singularly appropriate that you should have chosen this day for the le ture, for on the morning of this day twenty-seven years ago Sir Robert awoke and asked that the w eless from Australia be turned on to let him hear how the Test Match was progressing. All that day he was in good spirits, but when dusk drew on he seemed haunted by a premonition of another heart attack. On the evening of Saturday, January 14, 1933, he fell quietly asleep and only woke to pass away just before midnight.

" The orthopaedic surgeons who knew Sir Robert become fewer in number every year, but with that few there still flourishes a bond of affection and a memory that age cannot wither. God grant that those who succeed us will ever have for him that same love and respect that we have, and will look upon him as an example to exalt and in some small way to emulate, and that they will stand by those principles of orthopaedic surgery which by his own genius Sir Robert so moulded and fashioned that they stand at the very roots of the speciality to-day.

" He dies, having added lustre to the profession he loved and adorned."

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

A meeting of the Bone and Tooth Society was held at the Royal College of Surgeons on January 13, 1960, in three sessions, with Dame Janet Vaughan, Dr H. A. Sissons and Dr R. H. Mole in the chair. The subject was *Radioactive Materials and the Skeleton.*

Bone tumour production: dose response relationships using ^{32}P—*Dr J. P. M. Bensted* and *Dr N. M. Blackett* (London) described the production of bone tumours in rats after a single dose of ^{32}P and the histological changes leading up to tumour formation. The low incidence of tumours prevented valid conclusions about the relationship between tumour genesis and late histological changes. Dividing the same dose of ^{32}P into a number of injections at intervals of two weeks led to a very high incidence of tumours. Histological studies demonstrated a sequence of changes from " fibrosis " to malignant tumour, and the nature of this " fibrosis " was discussed. Some results were then presented on the time of appearance of bone tumours with repeated injections when the magnitude and timing of the injections were varied. Varying the size of the first injection from 1·0 to 0·5 to 0·25 μc/gm. while keeping the four repeated injections of 0·5 μc/gm. (at two-week intervals) constant caused little change in the time or rate of appearance of the bone tumours. Reducing the dose from $1{\cdot}0+4\times0{\cdot}5$ μc/gm. at two-week intervals to $0{\cdot}5+4\times0{\cdot}25$ μc/gm. at the same intervals greatly delayed the appearance of tumours. Variation in the timing of the injections for the same total dose caused a change in the rate at which tumours appeared without altering the time for the first tumours to appear. The injection of 1·0 μc/gm. with 0·6 μc/gm. at four, six and eight weeks gave a greater tumour rate than when the repeated injections were given at either two, four and six weeks or six, eight and ten weeks. It was suggested that these results were most likely to be interpreted by studying the variation in the

radiation conditions within bone in conjunction with the histological changes rather than in terms of the timing and magnitude of the injections. Finally an effect in which a single dose produced more tumours in rats than the same dose given in three treatments at two-weekly intervals was reported using a dose of 3,000 r x-rays to one hind limb.

Damage to dental tissues in high-dose rabbit experiments—*Professor M. A. Rushton* (London) referred to histological studies on jaws of rabbits after single injections of ^{90}Strontium as weanlings, work undertaken for the Medical Research Council under Dame Janet Vaughan at Oxford. Radiographic appearances had already been reported to the Society by Surgeon Captain (D) W. Holgate, R.N. Animals which received 600 or 1,000 μc/kg. ^{90}Strontium as weanlings had been killed at intervals from three to 180 days. By thirty days both eruption and growth of teeth in length were greatly retarded and dental pulps were much reduced. Dentine formation continued within the teeth so that they became more solid, and cells and capillaries were included in the new matrix. Apposition ceased on interdental alveolar bone but slow resorption continued: later lacunae became empty. By ninety days the teeth were quite solid and had ceased to grow, having only a small button of pulp at their base. After sixty days the basal part of the periodontal membrane and neighbouring marrow was invaded by pleomorphic osteoblastic tissue arising on the surface of bone of the socket. After 120 and 180 days similar proliferations appeared to have become inactive, leaving a residue of dysplastic bone or in some areas had produced highly cellular masses associated with resorption of adjacent tooth and bone. In rabbits injected at one year of age and killed after nine months osteosarcoma had arisen in the same relationship to teeth similarly affected and necrotic alveolar bone usually protruded into the mouth.

^{90}Strontium in the environment and human bone—*Dr F. J. Bryant* and *Dr D. H. Peirson* (Harwell) recalled that ^{90}Strontium was produced in large quantities in nuclear explosions; an explosion equivalent to 10^6 tons of trinitrotoluene produced 10^5 curies. Debris from explosions of kiloton bombs did not penetrate the tropopause and had a mean residence time in the troposphere of about thirty days. Debris from megaton bombs was injected into the stratosphere and the mean residence time might be as long as ten years. ^{90}Sr was important biologically because of its long half-life (twenty-eight years), and its deposition and retention in the bones; entry routes into the body were considered. Deposition of ^{90}Sr in rain was closely related to the total rainfall in a given period. The rate of deposition at Milford Haven was about 2·5 mc/km^2/year from 1954 to early 1958; the deposition for 1958 was 5·4 mc/km^2, and for January to June 1959 it was 4·1 mc/km^2. Tap waters derived from lakes in the United Kingdom contained ^{90}Sr 0·5 $\mu\mu$c/litre in early 1958 and 0·9 $\mu\mu$c/litre in early 1959; river waters contained about half as much, and well waters very little. The ratio of ^{90}Sr to calcium in femurs from persons who died in 1957–8 was highest for the age group nothing to five years. In the case of stillbirths there was a significant rise in the average value from 0·54 to 0·83 $\mu\mu$c/g of Ca between January to June 1958 and July to December 1958. ^{90}Sr in the range 0·1 to 0·4 $\mu\mu$c/g of Ca was found in third molar teeth from subjects aged seventeen to twenty-two and premolars from subjects aged nine to fifteen.

The relation of radiation damage to radiation dose from ^{90}Strontium—*Dr Sheila Macpherson*, *Dr Maureen Owen* and *Dame Janet Vaughan* (Oxford) said that young, growing rabbits injected with a high dose (500–1,000 μc/kg) of ^{90}Strontium generally died six to eight months later with multiple osteosarcomata, particularly in the upper tibial metaphysis, where the uptake of ^{90}Strontium was high. By an autoradiographic method, the radiation dose-rate had been measured at several sites in the tibia, and the corresponding histological damage observed at various intervals up to six months after injection. The dose-rates in the epiphysis and metaphysis were high initially (up to 50 rads/hour) but fell off rapidly; in the shaft the dose-rates were lower but remained steady. Damage to individual cells was seen when 75 rads had accumulated, at a rate of about 9 rads/hour. Osteoblasts largely disappeared from the metaphysis after 1,600 rads at the rate of about 20 rads/hour. Osteocytes were damaged with an accumulated dose of 2,000 rads. The marrow was very radiosensitive: a few hundred rads caused gross damage. A possible early stage in osteosarcoma occurred three months after injection, when the accumulated dose was about 13,000 rads. At short times after injection a fairly accurate estimate of accumulated dose could be made, but after six months the accuracy of the estimate might be no better than $\pm$50 per cent. This estimate might possibly prove too high, because the tissues received a total dose greater than that actually necessary to produce the damage. These results with this long-lived isotope did not shed much light on the relative effects of dose-*rate* and *total dose*, or on the importance of the *continued* irradiation of damaged but repairing tissues.

Retention of an intravenous dose of radioactive Strontium in man—*Dr G. E. Harrison* (Harwell) reported a study of the excretion and retention of a single intravenous dose of Strontium in two normal adult men. Each had an injection of 0·5 μc. of ^{85}Strontium, a gamma ray emitter of half-life sixty-five days.

Urine and faeces were collected for about 140 days and the retention, =dose−excretion, compared with that obtained from a whole body counter. The retention was followed up to one year by measurements of body radioactivity in this counter. The retention of the dose could be represented by a relationship either of the form $R = 51t^{-0.23}$, where R = per cent dose retained after a time , or by a three-term exponential expression. The turnover of the dose could arbitrarily be divided in three phases: 1) in which 70 per cent of the dose was excreted in about twenty days, mainly through the kidney, 2) in which 15 per cent of the dose was excreted with a half-life of about fifty days, 3) a chronic retention amounting to about 15 per cent of the dose for which the excretion rate was quite small. These three phases may be related to the degree of binding of Strontium in calcified tissue. The calculated radiation dose to bone for 1 μc. of ^{90}Strontium in 300 days, assuming a uniform distribution of radioactivity throughout the skeleton, was 0·46 rads.

Anatomical sites of deposition of ^{45}Ca in bone—*Professor P. Lacroix* (Louvain, Belgium) made his presentation in two sections, the first dealing with compact bone, and the second with growing bones. The interpretation of ^{45}Ca autoradiographs of compact bone required, first of all, knowledge of Haversian remodelling. Some progress had been made recently in the study of this process. The formation of the preosseous layer in a depositing osteon occurred in two stages which had been characterised histologically. During the second stage nucleation of apatite crystals began. Immediately after nucleation the load of calcium increased enormously to reach in a short time three-quarters of the final capacity. The large and dense imprints seen on ^{45}Ca autoradiographs of compact bone were due to heavy calcification of the depositing osteons. Small and weak imprints were also seen and these corresponded to the vascular canals, seven hours after injection; most of them disappeared but some persisted after twelve days; the former were presumed to correspond with short-term exchanges and the latter with slow osteogenesis. The diffuse reaction of the fully calcified bone was not seen at seven hours and took some days to appear; the phenomenon was explained by a process of long term exchange. The second section of the presentation was devoted to comment, in terms of histology, of the ^{45}Ca autoradiographs of growing bones. In the newborn puppy, bone trabeculae very soon reached their final size and their final calcification. After three weeks there was always in the long bones a particular region where bone tissue was more stable than elsewhere. At this stage transverse growth occurred by the peripheral deposition of thick layers of bone, the structure of which was still undetermined, and Haversian remodelling was being initiated. About nine weeks later transverse growth occurred mainly by a process of deposition of rows of osteons under the periosteum. Such osteons were called " addition osteons " and were slightly different from the " substitution osteons " of the Haversian remodelling. The growth of the vertebral column also had been studied. ^{45}Ca autoradiography revealed that enlargement of the vertebral canal was due to a correlation between bone formation and bone destruction.

Biological implications of radiation dosage to bone from environmental radioactive material—*Dr L. F. Lamerton* (London) stated that estimates of the risk of severe late effects from low levels of radiation involved very great assumptions, and were likely, in the present state of knowledge, to be of little value. In the production of bone tumours after radiation, clinical and experimental data strongly indicated that gross tissue damage by the radiation played an important part, but little was known about what precise types of damage were significant. Until more experimental data were available there was no basis for extrapolation from high dosage to low dosage. Too much preoccupation with the problems of extrapolation could easily lead to the wrong sort of experimentation. A much more fruitful approach lay in the recognition that radiation, and in particular by the bone-seeking isotopes, could provide most valuable tools in the study of basic mechanisms of carcinogenesis, but this implied some change in present emphasis from purely statistical to pathological studies. Finally, for a true appreciation of the biological significance of environmental radiation, effects occurring at low dosage must be considered in the general context of changes occurring naturally within the tissues.

Entry of ^{90}Strontium into human diet—*Dr R. Scott Russell* (Wantage) said that ^{90}Strontium released into the environment could enter into the human body by three means: inhalation, in drinking water or in food. Diet alone would be discussed because the other two sources were known to be very small by comparison. Fission products deposited from the atmosphere on to agricultural land might either lodge on vegetation or enter the soil. It was most important to assess the relative extent to which the ^{90}Strontium in diet was due to direct contamination as opposed to absorption from the soil because the extent of the former would be determined by the rate of fall-out, whereas the latter would be more dependent on the cumulative total so far deposited. Evidence of many types now indicated that direct contamination was of major importance. A particularly striking example was the perennial pastures from which cattle derived their food; a major route of contamination in this instance was " plant-base absorption," namely, the absorption of material entrapped in the " mat" consisting of surface roots, prostrate stems and leaves which develop on the soil surface. From this foliage

on the soil surface absorption of ^{90}Strontium can occur more readily than from the soil, where the contaminant is "diluted" by soil calcium. The contamination of grain crops had also been shown to depend largely on direct contamination. Considerable differences must be expected between different regions, but it was believed that during 1958 in the United Kingdom the level of ^{90}Strontium in milk was some five times greater than it would have been if the cumulative total of world-wide fall-out had been incorporated in the soil.

The two major problems in determining the quantity of ^{90}Strontium in the diet of a population were first, in obtaining representative samples and, second, in conducting elaborate radiochemical assay. Because dairy products were known to be the major source of ^{90}Strontium in the United Kingdom diet, particular attention was paid to the collection of representative samples of milk in the current surveys in the United Kingdom (Agricultural Research Council Radiobiological Laboratory Report ARCRL 1, H.M.S.O., 1959). Depots which handled over 40 per cent of the country's total production were sampled twice each month and the milk was bulked according to a statistical plan which gave samples representative of the total production of different regions. It was found that in 1958 the mean ratio of ^{90}Strontium to calcium in the average diet in the United Kingdom was about 6 $\mu\mu$c per g. After milk and milk produce, which contributed some 65 per cent of the total, vegetables and flour were the major sources of ^{90}Strontium (each 10–15 per cent). Fish and meat are very minor sources. Variations in composition of the diet had little effect on the mean ^{90}Strontium content, except that the substitution of wholemeal flour for white flour could cause a considerable increase.

Radiation dosage to bone from all sources—*Professor F. W. Spiers* (Leeds) said that the radiation dose in bone containing radioactive materials depended on the range of the ionising particles, the linear dimensions of the deposit and its location with respect to the significant biological structures. An alpha-particle emitter, such as radium, localised in Haversian systems or in trabeculae, produced a high dose in osteocytes lying within the deposit, lower doses to cells lining the Haversian canal or lying adjacent to trabeculae, and only a small dose to trabecular marrow which for the most part lay beyond the alpha-particle range. If similar depositions of ^{90}Strontium occurred, irradiation by the relatively long-range beta particles produced a more uniform pattern of dose but one in which trabecular marrow received about half the dose received by parts of the mineral bone containing the isotope. Sources of radiation external to the body, and beta-emitters and gamma-emitters widely distributed within the body, produced a nearly uniform dose to the whole skeleton. The general radiation sources affecting man (in this country) amounted typically to about 84 m. rem/year in hard bone and about 91 m. rem/year in trabecular marrow—the bone dose being lower because of the smaller ^{40}Potassium content of mineral bone. Alpha-ray doses from the natural levels of radium and mesothorium in bone were typically 32, 17 and 2 m. rem/year respectively to an osteocyte, the tissues lining a Haversian canal and trabecular marrow. The level of ^{90}Strontium in children's bones contributed doses of about 4, 4 and 2 m. rem/year respectively to the same tissues. The range of doses from the radium and thorium series extended, in this country, from about one-third to three times these figures, but the total dose to bone varied from about 80 to 200 m. rem/year.

Bone-seeking isotopes as indicators of bone turnover—*Dr G. C. H. Bauer* and *Dr B. Wendeberg* (Malmö, Sweden) considered that the use of radioactive isotopes for the study of bone had now reached beyond the stage of methodology and yielded data of immediate importance for interpretation of bone physiology and pathology. Isotope studies of fractures in human subjects were discussed, and it was shown that fracture of the shaft of tibia caused an increased rate of metabolism not only in the fracture area but also in the upper part of the tibia and in the femur. In addition, previously published work was reviewed, the references to which are as follows:

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SOUTH-WEST ORTHOPAEDIC CLUB

The autumn meeting of the South-West Orthopaedic Club was held on November 21, 1959, at the Prince of Wales Orthopaedic Hospital, Rhyd Lafar, Cardiff. Mr D. N. Rocyn Jones was in the chair. In the morning short papers were discussed.

Abdominal neuromyotomy—*Mr A. W. Fowler* (Bridgend) described an operation for correc on of flexion and adduction spasticity in both hips. A single abdominal incision was used in th lower abdominal transverse crease running from one anterior superior iliac spine to the other. It vided the rectus sheath, rectus muscles and lateral abdominal muscles. The inferior epigastric arteri were clamped and divided. By extraperitoneal dissection the bladder was displaced downwards and t e wall of the pelvis exposed. It was possible to divide completely or partly the obturator nerves a d the iliopsoas muscles. If hip flexion was to be retained only the psoas part of the iliopsoas sh ld be divided. If knee extension was to be retained the femoral nerve should be dissected out of the liacus sheath before the muscle was divided. The rectus sheath was sewn with strong thread; the ectus muscles were not repaired. The presence of hip or knee contractures might necessitate tenc omies in addition.

In reply to a question, Mr Fowler said that there was no danger of hernia through the ound provided non-absorbable sutures were used. Division of the recti was not only harmless, but elped to relieve abdominal spasm. He stressed that this was a palliative procedure to help the nur ng of patients with incurable paralysis or spasticity. The histories of three patients were describ l and illustrations shown.

Internal fixation for McMurray osteotomy—*Mr D. M. Jones* (Bristol) described his applian e for internal fixation of the McMurray osteotomy, mainly applicable in fractures of the neck of the f mur. The plate was stoutly made and was angled 45 degrees at its mid-point. It was joined to a trifi n nail the collar of which was dome-shaped allowing for a certain amount of adjustment between the na l and the plate. Fixation between the two was obtained by using a special washer; there were six w shers of varying shapes, the most appropriate one being selected. By this method complete displacem nt of the shaft of the femur under the acetabulum and the head of the femur could be obtained, and the plate did not encroach on the area between the trochanter and the lateral surface of the upper shaft of the femur and so hinder the formation of new bone. A number of illustrations were shown. Mr Jones said that all the operations in which he had used this appliance had been successful and there had been no complications. Discussion followed on the different types of fixation for McMurray osteotomy and their advantages.

An evaluation of bone stimulation for leg discrepancy—*Mr G. S. Tupman* (Bath) read a paper on the evaluation of bone stimulation for discrepancies of leg length. This paper was an analysis of twenty-eight patients with leg discrepancy who had fifty-one stimulating operations. Twelve patients were subjected to single bone stimulating operations between 1952 and 1955 at the Lord Mayor Treloar Orthopaedic Hospital, Alton. The remainder of the thirty-nine operations on sixteen patients were performed at the Bath and Wessex Orthopaedic Hospital. Twenty-two patients had leg discrepancy from old anterior poliomyelitis, five had congenital short legs and one had a discrepancy from old infective arthritis of the knee.

An accurate radiographic technique for measuring leg discrepancy was described, also the operative technique. Beef-bone pegs were inserted into the juxta-epiphysial area of the metaphysis; in six patients ivory pegs were used instead of bone. Four patients had osteotomies of the fibula in addition. The results showed that in no patient could a positive gain of the short over the long leg be obtained, but in twelve out of sixteen patients—that is, 75 per cent—arrest of increasing discrepancy was obtained, more particularly if the stimulating operation was repeated. In all twelve patients the operations were performed before puberty. During puberty, in three patients out of sixteen (representing 19 per cent), no effect whatsoever on the discrepancy was achieved by repeated stimulating operations and the discrepancy had to be corrected by growth arrest on the long side. It was emphasised that in studies of this sort previous growth patterns are essential to ensure that the discrepancy is still increasing, and accurate bone length measurements are important when dealing with small increments of growth.

Medullary nailing—*Mr M. Alms* (Bristol) presented a further paper on medullary nailing. The first fifty examples of medullary nailing for fractures of the tibia were briefly reviewed. The average period off work when the operation was well performed was just over nine weeks. When some error of technique occurred, this period was just over twenty-two weeks. The period for the total number of single fractures of one tibia was three months. Seventeen fractures of the forearm bones treated by medullary nailing were presented. The standard procedure suggested was closed nailing of the ulna with a quarter-inch clover-leaf nail to restore the stability of the limb, and then fixation of the radius by a 2·5-millimetre guide wire after exposure of the fracture, the cancellous reamings from the ulna being used as an immediate graft. Four examples of closed nailing of fractures of the shaft of the humerus were presented. A large nail of 11-millimetre or 12-millimetre diameter was introduced through the olecranon fossa, restoring immediate stability to the limb. There was rapid and easy return of function. These patients were all elderly and difficult to treat conservatively. Some examples were shown illustrating the application of medullary nailing to fractures of the metatarsals, metacarpals and

phalanges. Nailing of the fibula was presented as a useful means of preserving full length of the leg in certain compound fractures of the tibia after removal of the loose fragments. The key to success in all methods of intramedullary nailing was preliminary reaming of the bone.

Synovial cysts of the fingers—*Mr R. Merryweather* (Gloucester) presented a paper, illustrated by slides, of the lesions known as synovial cysts of the fingers; most had been dealt with by excision and skin grafting. There had always been some difference of opinion on the etiology of these cysts, which were usually confined to the dorsal surface of the terminal finger joints. In those described the content of the cysts was undoubtedly like synovial fluid and could not be confused with the jelly-like content of a ganglion. In certain instances a pinhole communication with the joint was demonstrated.

Neurological disorders that may appear in a foot clinic—*Dr C. Wells* (Cardiff) stressed the recent work on physical sensation which had been published by Wedell of Oxford. He described those neurological conditions producing pain or weakness in the foot that could be overlooked. A clear classification of the various causes of foot drop was described, together with an illustrated pattern of the neurological signs that could help in diagnosis. This paper by a neurologist was received with great interest by the members of the Orthopaedic Club.

Transthoracic surgery of the spine—*Mr H. J. Richards* (Cardiff) had found the transthoracic approach to the spine to be the best and easiest exposure to the bodies and pedicles of the vertebrae. It gave an excellent exposure for draining abscesses, fusing unstable spines, carrying out certain procedures on patients with scoliosis and for biopsy of the vertebrae. Coloured slides of the operation were shown. Radiographs were demonstrated and clinical cases were presented. These were: 1) a congenital kyphoscoliosis from an abnormality in the development of thoracic vertebra 9; 2) a rapidly developing tuberculous lesion of the cervico-thoracic junction with abscess formation; 3) a long standing case of tuberculosis involving the mid-thoracic region of the spine with an abscess which had been present for twelve years; 4) a mid-thoracic lymphoblastoma that had been operated upon and irradiated. Because there was no recurrence four years later and as the spine was gradually deforming, the spine was stabilised by an anterior bone-grafting operation. All patients presented had been followed for three years after the operation.

Forefoot reconstruction—*Mr A. W. Fowler* (Bridgend) presented three patients on whom he had performed his operation of forefoot reconstruction. In this operation all the metatarsal heads were removed through a dorsal incision and a generous ellipse of skin and subcutaneous tissue was then removed from the sole of the foot. All patients had very severe fixed claw toes and had been unwilling to submit to removal of all the toes. They were all pleased with the results.

Recurrent dislocation of the elbow—*Mr H. J. Hambury* (Swansea) presented a boy aged eleven years who had dislocated his left elbow eighteen times between the ages of four and ten years. The operation described by Reichenheim was used; the biceps tendon was exposed and divided through Henry's approach and reattached to the tip of the coronoid process of the ulna with two wire sutures. The operation was done in September 1958, and for fourteen months after there had been no recurrence. The arm had normal strength and elbow function was full. This condition was reported in the British literature in 1947. Other operations recommended for it were deepening of the joint surface of the ulna by insertion of a bone peg into the coronoid process (Milch), or by forming a musculotendinous loop of parts of the biceps and triceps pulled through a hole in the olecranon fossa of the humerus (Harding).

Eosinophilic granuloma of bone—*Dr D. Evans* (Cardiff) presented four examples of eosinophilic granuloma of bone with special reference to their mode of onset, radiographic appearance and histology. All had presented within the last three years. Biopsy was important in diagnosis, the condition often being indistinguishable even radiographically from a simple bone cyst, osteomyelitis or neoplasm. Healing followed limited curettage with or without bone grafting. The relationship of eosinophilic granuloma to the other forms of histiocytosis (Hand-Schüller-Christian syndrome and Letterer-Siwe disease) was discussed. It was thought that when only one bone was involved by eosinophilic granuloma healing was the rule; that when several bones were involved healing was only probable; that when a succession of new lesions appeared there was need for a guarded prognosis; and that the appearance of visceral involvement was ominous. The need for longer follow-up and investigation into the etiology of the condition was stressed.

EAST ANGLIAN ORTHOPAEDIC CLUB

A meeting was held at Thorpe Hall Rehabilitation Centre, Peterborough, on November 27, 1959. Clinical cases were shown.

Mr Noel Smith began by discussing some unusual hip conditions:

Tuberculous arthritis of hip—The first patient was suspected of having tuberculous arthritis of the hip but the diagnosis was not confirmed until a drilling operation on the right femur seemed to light up the condition. Radiographic changes appeared two years after the onset of symptoms.

Sarcomatous change in Paget's disease—The next was a patient with Paget's disease and osteoarthritis of the hip. An attempt to arthrodese the hip was not successful; later radiographs showed further destruction of the bone and biopsy revealed a chondrosarcoma. Hindquarter amputation was refused; radiotherapy and radioactive synkavit were tried without success.

Multilocular cyst of femoral neck—A multilocular cystic condition of the femoral neck of a child was cleared out and the cavity filled with bone chips taken from the father's ilium. The condition recurred and advanced. A discussion followed on the best treatment; some advocated radiotherapy, others suggested waiting and, if necessary, further chip grafting when bone growth had stopped.

Benign giant-cell tumour—A boy of sixteen had a benign giant-celled tumour treated by radiotherapy. He sustained a fracture of the femoral neck and the tumour healed leaving some coxa vara. The residual deformity was corrected by a subtrochanteric osteotomy with internal fixation by McLaughlan nail and plate. The boy later developed degenerative arthritis of the hip.

Sarcoma of the calcaneum—*Dr W. De Souza* showed a sarcoma of the calcaneum in a woman aged ninety-one. It had been present for three years and was treated by a below-knee amputation; it was found to be an osteogenic sarcoma arising in Paget's disease.

Compound palmar ganglion—*Dr De Souza* showed a man with a painful swelling of the calf that had been present for a year. At operation it appeared to be a compound palmar ganglion; this was later confirmed by the histology.

Tumours of forearm—*Mr A. B. King* described a child of thirteen years with an osteoclastoma in the shaft of the radius. This was excised and the gap filled with a tibial graft which failed to incorporate.

Mr Noel Smith mentioned a similar tumour occurring in the ulna of a girl aged fifteen years which looked like a sarcoma. He excised the shaft of the ulna widely and bridged the gap with an onlay tibial bone graft screwed to the upper end of the ulna and firmly impacted into the lower end.

Dislocation of the wrist—*Mr R. Stephenson* demonstrated two patients with dislocation of the wrist with displacement of the scaphoid and semilunar bones. In one patient complete reduction was obtained but in the other the scaphoid bone remained displaced and at open operation was found to be lying completely loose.

"Tennis" elbow—*Mr Noel Smith* then discussed "tennis" elbow and said that he had treated patients by physiotherapy, manipulation, injections of hydrocortisone and division of the insertion of the extensor mass and had had recurrences in all of them, until, after dividing the extensor mass and exposing the radio-humeral joint, he noticed a tag of synovial membrane. He now removed this tag and stated that "this does cure 'tennis' elbow." Discussion followed and doubt was expressed; Mr Noel Smith was asked to produce photographic evidence.

AUSTRALIA

AUSTRALIAN ORTHOPAEDIC ASSOCIATION

The Annual General Meeting of the Australian Orthopaedic Association was held in Perth, Western Australia, on August 17–21, 1958. This was the first meeting held in Perth since the war and was well attended by some forty-six members. Professor K. Kallio of Finland and Dr Arnt Jacobsen of Norway attended as guests.

Presidential address—*Mr J. Colquhoun* (Melbourne), the retiring President, delivered his address on August 18. He described his recent visit to Washington for the Combined Orthopaedic Meeting of the English-Speaking Countries, in particular the presentation of the gift from the Australian Orthopaedic Association to the American Orthopaedic Association at the conference dinner. He suggested that the next Joint Meeting might be given in Australia. He also described various other centres in America and Honolulu and Europe and the men he had met and their ideas.

The place of surgery in treatment of congenital dislocation of the hip—*Mr E. Price* (Melbourne) stated that congenital displacement of the hip occurred in two forms, subluxation and dislocation. He thought that a third form sometimes described as congenital dysplasia was simply minimal subluxation. Subluxation and dislocation were fundamentally different, in that a "limbus" was present in dislocation but not in subluxation.

In congenital dislocation of the hip manipulative reduction was the method of choice, but not all patients could be managed by closed reduction. Some could not be reduced at all by manipulation, others showed dysplasia and degenerative changes, and others a gradual reappearance of subluxation proceeding over ten to fifteen years. In his own department a group of fifty-two patients, all less than

four years of age, were reviewed, all treated during the three-year period 1954 to 1956. 1) Subluxation accounted for 16 per cent; 2) closed reduction alone succeeded in 61 per cent of dislocations; 3) redislocation after closed reduction occurred in 17 per cent; 4) open reduction succeeded in 17 per cent; 5) acetabular reduction was impossible in 5 per cent. Fifty per cent showed avascular necrosis after closed reduction and 25 per cent after open reduction. Surgery has its place after closed treatment had failed. There were four indications: 1) unstable primary reduction; 2) late redislocation; 3) irreducible dislocation; 4) final failure of primary treatment.

Unstable primary reduction was caused mainly by limbus intrusion, as described by Somerville (1953). The limbus at reduction followed one of three patterns: 1) it might slip aside allowing concentric reduction; 2) it might form a diaphragm so that false reduction would occur, and the hip would redislocate; 3) it might be compressed with the acetabulum (eccentric reduction), and might subsequently atrophy or might persist, with later redislocation. Certain provisions were to be noted in the operation of limbectomy: 1) reduction must be effected without force; 2) the outlook must not be prejudiced by prolonged unsuccessful efforts at closed treatment; 3) effects of excessive anteversion must be taken into account in the after treatment; 4) the operative hazards must be circumvented.

Late redislocation might be caused by two mechanisms—intrusion of the limbus or excessive anteversion of the femoral neck. Exploration of the hip was indicated if the redislocation was rapid and marked, earlier evidence of eccentric reduction existed, or the arthrographs were equivocal but might demonstrate an intrusion. The treatment of redislocation caused by excessive anteversion was osteotomy.

Irreducible dislocation was caused by secondary changes in bones and ligaments. Slight degrees might be overcome by gradual abduction and traction, but there was a definite group unsuitable both for closed and open reduction. Various forms of arthroplasty, osteotomy and arthrodesis had been devised for this group. In general, excellent hips were not obtained by any of these measures and the prognosis without treatment must be assessed before any of them was undertaken. Pain was the chief indication for surgical intervention. The problem depended on the age of the patient. 1) Age of election, about the age of three years treatment might be performed by a period of traction and gradual abduction and then open reduction. 2) In early childhood, up to the age of six years, patients with unilateral dislocation would be improved by the arthroplasty devised by Groves (1926–27) and Colonna (1932). Patients with bilateral dislocation were probably best left alone if not in pain. 3) In adolescence arthrodesis was preferred for unilateral dislocation. In bilateral dislocation cup arthroplasty might be considered, preferably combined with osteotomy. 4) In adult life abduction osteotomy was probably best. The McMurray type was preferred to the Shanz type.

Final failure of primary treatment. 1) A mobile hip: the shelf operation sometimes gave a good result but the Colonna procedure was mechanically better. The shelf operation appeared to give more movement, but less stability, than the Colonna operation. 2) A hip stiff in position of deformity, usually caused by severe dysplasia from avascular necrosis, chondromalacia or prolonged treatment, was best corrected by a single osteotomy.

Conservative treatment of congenital dislocation of the hip—*Mr R. Jones* (Melbourne) presented this paper by invitation. Important developments had been made by Putti (1929) who advocated early diagnosis and treatment, Severin (1940–41), who introduced arthrography, and Denis Browne (1950) and Somerville (1953), who described dynamic splinting of the reduced dislocation. There were two methods of closed reduction: 1) traction in abduction, and 2) manipulation. A summary of thirty-two dislocated hips in twenty-one patients was presented. All of these had been treated by the Denis Browne method. The duration of follow-up was from ten months to seven years. Stability—all patients had stable reduced hips (100 per cent). Two patients required several manipulative reductions and splinting because of redislocation; in each of these the hip now appeared stable but showed osteochondritis of the femoral head and some limitation of flexion and medial rotation. The femoral epiphysis in eleven hips had radiological signs resembling those of osteochondritis. Mr Jones considered that the Denis Browne method had many advantages over other methods of conservative management.

Professor K. Kallio (Finland) believed that in China congenital dislocation of the hip did not exist. Was this because babies were carried on their mothers' backs with their legs abducted? *Mr W. Stening* (Sydney) described a recent case of failed reduction by closed and open methods in a child in whom the disease had been detected at eight weeks. *Mr A. Dwyer* (Sydney) considered that it was not always possible to make a diagnosis in early infancy. He believed that most cases required rotation osteotomy. *Mr A. Hamilton* (Sydney) described a child who had undergone several attempts at reduction, all unsuccessful, and was transferred to Colonna who operated successfully. He said that anterior dislocations were difficult to reduce, and that attempts to reduce the hips in arthrogryposis always failed. *Mr A. Watts* (Sydney) quoted McMurray who had stated that if he could not reduce a posterior dislocation but could make it into an anterior dislocation he would leave it in this position as the

results were not bad. *Mr P. Williams* (Melbourne) mentioned the value of lateral radiography and arthrography in confirming the accuracy of reduction. *Mr W. Gilmore* (Perth) said that after open reduction the limb must be put in medial rotation. He thought rotation osteotomy was no done often enough. *Mr G. Bedbrook* (Perth) mentioned one example of bilateral dislocation in which one hip became reduced in medial rotation and abduction and the other hip in lateral rotation and abduction. He believed that many dislocations were not demonstrable at birth. *Mr C. McNeur* (Melbourne) had noticed at open operation that all hips were stable in medial rotation. *Mr A. Rhydderch* (Sydney) thought that if radiographic evidence of reduction was not complete limbectomy was justified: the numbers of patients seen in adult hospitals with subluxation confirmed this view. *Mr K. Dawmond* (Sydney) mentioned that neonatal radiographs of hips should be taken in 30 degrees of abduction and full medial rotation. *Mr J. Lahz* (Brisbane) described two patients with unilateral congenital dislocation of the hip treated by the Denis Browne method; osteochondritic changes developed in the sound femoral head.

Foot stabilisation—*Mr P. Williams* (Melbourne) said that foot stabilisation was intended to correct deformity and instability and was offered to the patient as a permanent solution to the problems. However, it often failed to achieve these aims. Many results were initially imperfect, and there were often good early results that deteriorated later. There followed an attempt to analyse the causes of failure and describe the technique most likely to avoid them. Two types of foot stabilisation operations were considered: that which involved excision of joints as in the Naughton Dunn operation later modified by Lambrinudi and others, and that which involved a cortical inlay from the lateral side, recently popularised by Grice. Causes of failure were under-correction of the varus or valgus deformity, recurrence of the original deformity over the years from failure to correct muscle imbalance, and pseudarthrosis, practically unknown with the inlay grafting type of operation. Principles of management: 1) Soft-tissue correction must be obtained first: *a*) by wedged plasters to stretch the tendo calcaneus; *b*) by manipulation in spasmodic flat foot or paralytic deformities; *c*) by plantar fasciotomy and wrenching to overcome the cavus element; *d*) by tenotomy of the tibial tendons, especially tibialis posterior in spastic pes varus; *e*) by elongation of the tendo calcaneus if more than a one-half equinus deformity was present. 2) Control of muscle imbalance, for example: *a*) by transfer of the tibialis anterior tendon into the cuboid; *b*) by transfer of the tibialis posterior tendon forward through the interosseous membrane to the dorsum of the foot. 3) Principles of operative technique: the Ollier incision was advocated in the excision operations and the Campbell approach for the inlay technique; in the excision type of operation the minimum amount of bone should be removed. In the inlay grafting operation results were better if the graft was placed across both mid-tarsal and subtalar joints.

A medial and posterior release operation for club foot—*Mr A. McSweeney* (Brisbane) discussed the operations described by Brockman, Naughton Dunn, Staham, Wagner and Butterfield and others in the treatment of relapsed club foot. He mentioned the causes of unsatisfactory results in some of these operations, the late development of unsightly imbalance after transplantation of the tibialis anterior tendon, and particularly depression of the ball of the foot and clawing of the big toe from the overaction of peroneus longus and extensor hallucis longus. McFarland had also mentioned the danger of the formation of scar tissue in the concavity of an arc of growing bones after operations of the Brockman type. Mr McSweeney then described a method of operation with indebtedness to previous workers. This report comprised operations on twelve feet in nine patients.

Indications for operation were resistant or relapsed club foot in spite of two years of adequate conservative treatment. Principles of operation were: 1) to achieve lasting correction without precluding triple arthrodesis if it became necessary later; 2) to avoid cutting soft tissues which healed with gross scar contracture; 3) to supplement when necessary soft-tissue correction by restricted osteotomy; 4) to achieve correction of second stage operation and to avoid circulatory embarrassment; 5) to maintain immobilisation after operation for an adequate period and allow weight bearing during its later part; and 6) to eliminate the use of irons. *Technique of operation*—By a medial approach, tibialis posterior tendon was divided and also the capsule of the first cuneiform-metatarsal joint on medial, inferior and dorsal surfaces. This was followed by a capsulotomy of the joints between the navicular and the first cuneiform and between the head of the talus and the navicular. It was usually necessary to divide the deltoid ligament in its anterior and middle parts. The plantar calcaneo-navicular ligament was also divided and the interosseous talo-calcaneal ligament. The foot was immobilised in the corrected position in plaster. Four weeks later a further operation was done to lengthen the tendo calcaneus and divide the capsules and ligaments over the posterior aspect of ankle and subtalar joints. Occasionally wedge tarsectomy of the cuboid was necessary during the first stage, and sometimes during the second stage an osteotomy of the fibula to enable the talus to be placed in the joint mortise in dorsiflexion. Finally a below-knee plaster was applied, usually for three to four

months, then a lace-up removable below-knee celluloid case worn with an overboot for six months after operation.

Mr A. Watts (Sydney) suggested that rather than discard the tibialis posterior tendon it should be transplanted anteriorly to act as a dorsiflexor and evertor of the foot. *Mr E. Price* (Melbourne) said recent emphasis was on manipulative methods of treatment but that they were often disappointing. There was a time for dividing " bad " ligaments rather than stretching them. He mentioned two points about lengthening the tendo calcaneus: the heel was smaller because it was crushed between two inextensible structures; lengthening the tendon allowed normal growth of the calcaneum. The tendon acted as an invertor of the heel in club foot. He thought metatarsal osteotomy often valuable in metatarsus varus. *Mr L. Bonnin* (Adelaide) asked what were the special points to prevent scarring in Brockman's operation. *Mr A. McSweeney* (Brisbane) replied that gentleness in handling the tissues and clean incisions rather than exploration of the joints were important. Each ligament should be divided individually with an osteotome. Long plantar structures should not be divided, as in Steindler's operation, because this caused scarring.

The conservative treatment of persistent club foot—*Mr A. McNeur* (Melbourne) read a paper.

Morton's metatarsalgia—*Mr G. Kerridge* (Newcastle) presented clinical and pathological evidence that the essential lesion was endarteritis obliterans of the accompanying artery and suggested that the associated neuritis and neuroma formation were secondary to the arterial changes. *Mr J. Cloke* (Melbourne) added to the clinical picture as he, himself, suffered from metatarsalgia in both feet. He described the temperature disturbance, the toe sometimes hot, sometimes cold. His symptoms were related to footwear and the pain was worst in the morning when walking on a carpet in bare feet. *Professor K. Kallio* (Finland) had often operated without finding a typical neuroma but with good results. He agreed that the condition was primarily vascular. *Mr A. Dwyer* (Sydney) said that metatarsal bars often cured the condition. *Mr A. Hamilton* (Sydney) mentioned help in diagnosis; a small blunt instrument pressed into the interdigital cleft often reproduced the pain. He said that one must use a plantar incision for removal of the neuroma. *Mr A. Dawkins* (Perth) and *Mr E. Price* (Melbourne) described instances of a tiny cystic tumour on the nerve in a neurilemmoma which recurred.

Discographs in diagnosis of back disabilities—*Mr C. Hudson* (Sydney) described the method and the assistance it gave in diagnosis. *Mr T. King* (Melbourne) said there were three special methods of examining the spine: by radiographs to demonstrate instability; by myelography; and by discography. Discographs were used in very disabled patients with unstable vertebra demonstrated by radiographs; before operations in patients with neurological signs of a disc protrusion, the myelographs being often unreliable; and in gross disc degeneration with pain, even though disc degeneration was obvious.

The use of free skin—*Professor K. Kallio* (Finland) presented a film demonstration of the repair of tendons and ligaments, knee arthroplasty, and hip arthroplasty. *Mr A. Watts* asked why skin was placed on only one surface, and was told that hyaline cartilage developed in granulation tissue. *Mr A. Dwyer* asked the incidence of avascular necrosis: there had been no cases.

Vitallium cup arthroplasty in osteoarthritis of the hip—*Dr A. Jacobsen* (Norway) presented a film and paper on Vitallium cup arthroplasty in osteoarthritis of the hip, a review of 289 patients. The average duration of follow-up was four to five years; 57·8 per cent of patients were very satisfied; 24·6 per cent of patients were satisfied; 17·6 per cent were not satisfied. By clinical assessment, the results were excellent in 26 per cent, good in 37·4 per cent, fair in 22·8 per cent and poor in 13·8 per cent.

Syndrome of ruptured interspinous ligament and its repair by use of free skin graft—*Professor K. Kallio* (Finland) showed a film illustrating the syndrome of ruptured interspinous ligament and its repair by use of a free skin graft. He stated that this injury was often associated with disc prolapse. He illustrated a method of radiographic diagnosis by paraspinous injection of contrast medium, which passed to the other side through a hole in the ligament. It was repaired by skin from the edge of the incision. Replying to questions, he said that there was a clinical syndrome of low back and sciatic pain not unlike that due to a disc prolapse, that he used no particular contrast medium, and that in all suspected disc protrusions ligamentography was now done.

Pseudarthrosis of the neck of the femur—*Mr H. Hill* (Perth) showed radiographs of a girl of eight months with pseudarthrosis of the neck of the femur. When two weeks old she had developed an acute infection of the hip joint, with osteomyelitis of the neck of the femur and thrombosis of the internal iliac veins. The child was treated conservatively and walked at one year. Two years later a radiograph showed non-union of the neck of the femur; the patient was walking with a slight limp. Three years later a radiograph revealed further slipping of the epiphysis and an increasing coxa vara. At this stage a subtrochanteric osteotomy and cortical tibial grafting operation was done and two years later the

pseudarthrosis was united. *Mr E. Price*, mentioning a similar case, remarked on the normal dev lopment of the hip after bone grafting in a child. *Mr P. Williams* enquired whether this was not a case of congenital coxa vara associated with infection. *Mr A. Hamilton*, asking whether a caliper had been worn at all, was told it had not. *Mr J. Colquhoun* described a girl with a congenital sho leg and increasing coxa vara deformity and osteoporosis of the femoral neck. A subtrochanteric o eotomy was done, and union occurred in the femoral neck followed by fusion of the epiphysis, wit further shortening of the leg.

Renal rickets—*Mr R. McKellar Hall* (Perth) showed a man of twenty-four years with unst le legs. He was all right when standing or walking but after sitting he could not stand up again vithout difficulty. He was thought to be suffering from renal rickets; there was considerable bowi of the lower limbs. Osteotomy had been performed on both upper tibiae and femora. *Mr T. King* scribed the disability to slipping patellae and considered that nothing should be done. *Mr R. Ho kinson* advocated multiple osteotomies, maintained by intramedullary nailing. *Mr A. Hamilton* recon mended a high tibial osteotomy and derotation of the lower limb, and possibly a femoral osteoto also. *Mr C. McNeur* also advocated femoral osteotomy.

Congenital pseudarthrosis of the tibia—*Mr W. Gilmour* (Perth) showed a child of two with co genital pseudarthrosis of the tibia and an equinovarus deformity of the foot. The deformity of the f t was partly corrected with strapping and plaster fixation. He was fitted with a caliper when fit t walk. *Mr H. Hill* (Perth) showed another case. *Mr E. Price* said there were three types of this co lition: that complicating monostotic fibrous dysplasia, curved tibia, and in twin births. There was d ficulty in fixation of the area. If union was not obtained in three weeks, the area was disturbed w n the plaster was changed and non-union gradually occurred. He said the average number of bon grafts before successful union was seven. He had tried operations with donor grafts and Cha ley's compression method without success. Intramedullary nailing had failed. Union should be ob ained before the age of two if possible: probably the chance of union was lost at three or four. He sed a double hip spica after operation. He thought that Charnley's method had the best chance of s cess. *Mr R. Hodgkinson* mentioned that Boyd recommended grafting bowed tibia to prevent fra ture. *Mr C. McKellar* described two children in whom amputation was performed at the age of seven ears. He mentioned a patient in whom grafting had been done; but at the age of fourteen the limb was four inches short and the patient wanted an amputation. *Mr H. Barry* (Sydney) agreed with amput tion in these patients. *Mr P. Williams* was against amputation. He mentioned four patients with b wed tibiae, all fitted with an extension prosthesis with excellent results, a good end-bearing stump being obtained. *Mr A. Hamilton* agreed that amputation should be avoided if possible, because of troubles with the stump. *Mr K. Daymond* described a case in which four grafts had been unsuccessful.

Chronic bone abscess—*Mr A. Cromack* (Perth) showed a patient with a chronically infected bone cavity that had been present for seventeen years and had never been healed for longer than ten weeks at a time. Many operations had been performed including curettage and plastic procedures. The infection had followed a gunshot wound and the adjacent knee was ankylosed. Four months before, the cavity was curetted and filled with bone chips. *Mr A. White* (Adelaide) thought that the cavity should be covered with a cross leg skin flap. *Professor Kallio* had used a free skin graft in a chronic cavity which healed; the cavity must be covered, and he suggested a pedicle muscle flap to fill the cavity. *Mr W. Gilmour* (Perth) thought immobilisation important and that slight movement favoured chronicity in these lesions.

Brachial plexus injuries with vascular damage—*Mr W. Parnell* (Perth) described two patients with traumatic brachial plexus lesions. 1) A man of fifty-six years was unconscious, with a dislocated shoulder, anaesthesia of the upper limb and loss of pulse. Some patchy return of sensation occurred over the next month, but the pain recurred and the anaesthesia became complete. Operation was performed. The clavicle was divided and a large aneurysm of the axillary artery found. This was repaired, and slow recovery followed except for residual paralysis of the intrinsic muscles of the hand and the deltoid muscle. 2) A boy of fifteen years broke the upper third of his humerus, the radial pulse was absent and there was a brachial plexus lesion. A tense swelling in the axilla with an audible bruit was present. Arteriographs showed a normal axillary and brachial artery but the profunda vessel was missing. At operation the radial nerve was found divided at the site of fracture and was repaired, and absence of the profunda artery was confirmed. Six weeks later the brachial plexus was explored. There was much fibrosis but no actual tear. Later the humerus was bone grafted. There had been partial recovery only over twelve months. *Mr A. Dwyer* mentioned a patient with serratus anterior paralysis after a fall on the shoulder; there was no recovery. *Mr G. Bedbrook* mentioned a similar patient who improved for a long time. *Mr E. Price* described a child with a complete brachial plexus lesion after a traffic accident. There was no recovery after eighteen months, and

amputation was suggested. Without operation gradual recovery occurred and he regained a useful hand. *Mr P. Williams* said that recovery was possible over a period of three years.

Multiple congenital deformities—*Mr G. Bedbrook* (Perth) showed two patients. 1) A child with talipes equinovarus in one foot, talipes calcaneovalgus in the other, bilateral congenital dislocation of the hips, stiff knees and an anomaly of the spinal cord with partial paraplegia. The right hip showed a posterior dislocation and the left hip an anterior dislocation. The right hip was reduced and treated in lateral rotation and the left hip in medial rotation. 2) A child with bilateral talipes equinovarus, bilateral congenital dislocations of the hips, and bilateral deformities of the knees. Osteotomies had been performed at the hips and derotation osteotomies of both upper tibiae. He now had some flexion contracture of the hips. The prognosis was reasonably good.

Tumours of the head of the humerus—*Mr A. Dawkins* (Perth) showed two patients. 1) A man of fifty-four years with a tumour of the head of the humerus. This was found to be a chondromyxofibroma of bone. Operation was performed for biopsy and curettage, followed by radiotherapy. Pain recurred and a further operation was performed to remove the upper end of the humerus. The tumour was benign but complete extirpation was not possible by curettage. 2) A man with an erosive lesion of the head of the humerus. Biopsy revealed a low grade form of sarcoma, a parosteal sarcoma. The upper end of the humerus was removed.

On Thursday, August 21, 1958, further cases were presented.

Chronic septic arthritis caused by foreign bodies—*Mr A. Rhydderch* (Sydney) showed two patients. 1) A young boy with chronic infective arthritis of the ankle, diagnosed as tuberculous. He had several months' immobilisation and antibiotic therapy followed by arthrotomy; a large piece of wood was found in a disorganised joint. There was no history of injury. 2) A young boy sprained his ankle; fever and swelling of the foot and ankle developed. An operation was performed and sterile pus found. There was a continuing intermittent sinus. A further operation revealed a large wooden splinter in the joint. *Mr R. McKellar Hall* described a recurrent swelling of the ankle. Two years later a large palm thorn was extruded. *Mr A. Hamilton* described a swollen and painful knee; a piece of wood was removed from the joint. *Mr A. McSweeney* mentioned a tumour of the arm after a car accident; a car door handle was found. *Mr W. Parnell* and *Mr E. Price* described comparable cases.

Fatigue fractures—*Mr C. Hudson* (Sydney) described fatigue fracture of the femur in a young milkman after two or three months of jumping up and down from his cart. *Mr R. Hodgkinson* told of an adolescent boy who was a high jumper and developed a painful shin due to a fatigue fracture of the tibia, and also of a woman with stress fractures of the second metatarsal bone treated with a metatarsal bar, who developed stress fractures of both third metatarsals. *Professor K. Kallio* said that march fractures occurred often in young boys in Finland doing military training, and also occasionally fatigue fractures of the tibia. *Mr J. Colquhoun* said that march fractures were common after prolonged immobilisation for tuberculosis. *Mr A. Hamilton* and *Mr A. Dwyer* contributed further cases. *Mr A. Watts* mentioned a spontaneous fracture of the neck of the femur in a boy of twelve suffering from marble bones.

Instability of fifth cervical vertebra on sixth after a car accident—*Mr G. Kerridge* (Newcastle) presented a woman injured in a car accident, with "neck jerk" injury. The radiographs were normal and a felt collar was applied. Later radiographs were done in flexion and showed rupture of the posterior ligament between the fifth and sixth cervical vertebrae, with extreme angulation. The patient recovered with immobilisation. *Mr A. Hamilton* stressed that all neck injuries should be radiographed in flexion.

Cineplastic amputation of the forearm—*Professor K. Kallio* (Finland) showed a film illustrating the technique and results of cineplastic amputation of the forearm, which he employed in double amputees and blind people.

Excision of the medial epicondyle for ulnar neuritis and compression treatment of infected fractures—*Mr T. King* (Melbourne) showed two films: 1) of the technique of removal of the medial epicondyle in the operative treatment of ulnar neuritis, and 2) of the compression technique for infected comminuted fractures.

Osteochondritis dissecans of both knees—*Mr A. Hamilton* (Sydney) showed a patient with osteochondritis dissecans of both knees, treated conservatively in a Thomas's knee caliper with a good result. He also used a back splint at night. *Mr R. Hodgkinson* thought that calipers were unfortunate for young boys at school and usually preferred operation. He described Gallie's technique of pegging the fragment with a bone graft with good results. *Mr J. Colquhoun* said that in early cases a splint should be used to prevent full flexion of the knee. *Mr A. Dwyer* mentioned Glissan's work in this condition, with

conservative measures to avoid full flexion only. *Mr H. Hill* disagreed with the use of a liper, recalling that spontaneous healing was common. *Mr T. King* thought a caliper necessary onl if the fragment involved a weight-bearing surface.

Resection of large osteoclastomata—*Mr P. Williams* (Melbourne) showed methods of resectin large osteoclastomata. In a woman with a large tumour of the lower end of the femur the lower sixt of the femur was resected, the excised fragment autoclaved and then reattached by a long Küntsch r nail across the knee joint. She wore a caliper for five months. In spite of slight telescoping, s was walking now, one year after operation, with a stiff knee and three-quarters of an inch of shor ning. In a man with a large osteoclastoma of the upper end of the tibia the affected part was resect l and replaced by a similar piece previously removed from a cadaver. It was autoclaved first and fix with a Küntscher nail.

Unusual uses of the Küntscher nail—*Mr Williams* also showed a woman with a comminuted f cture of the shaft of the femur with chronic infection who had been treated by Küntscher nailing onl with a satisfactory result, and a woman with an old-standing ununited fracture of the humerus treat with Küntscher nail only, with good result. *Mr J. Cloke* had resected the lower end of a woman's emur for osteoclastoma and filled the space with a bone block with a satisfactory result. *Professor K. Kallio* described a method of cauterising the tumour and then immobilising the part. Results were pro ising. He thought that treatment was surgical, not radiotherapeutic. *Mr J. Lahz* mentioned two patien with adamantinoma of the mandible. The bone was resected, boiled and replaced. The condyle and n ck of the mandible absorbed in both these patients. *Mr J. Jens* (Melbourne) and *Mr E. Price* describe cases of resection of tumours and replacement by faggot or fibular grafts.

Transthoracic spinal fusion—*Mr H. Barry* (Sydney) described one example of transthoracic spinal f sion in a woman weighing 15 stones, with multiple tuberculous foci. He followed the technique des ibed by Hodgson (Hong Kong). In this patient two separate thoracic lesions were dealt with. *Mr R. Hodgkinson* said that he saw Professor Stocks do this operation on a child of three years. The difficult level was the lower cervical/upper thoracic region. *Professor K. Kallio* thought the oper ative risk was high. *Mr T. King* thought the patient had been operated on prematurely with no attempt at conservative treatment.

Recorded operations by Smith-Petersen—*Mr J. Colquhoun* (Melbourne) showed some historical slides of operations performed by Smith-Petersen in 1927.

Recurrent dislocation of the elbow—*Mr W. Gayton* (Melbourne) showed a soldier of twenty-nine with recurrent dislocation of the elbow, in whom the tendon of the biceps was transferred to the ulna and fixed with Bunnell type pull-out wire. *Mr J. Lahz* pointed out that in recurrent dislocation of the elbow the capsule is detached from the front of the humerus. He had performed direct suture in one case with good result.

Prosthetic replacement in fracture of femoral neck in Paget's disease—*Mr W. Gayton* (Melbourne) described a fractured neck of the femur in a patient who had Paget's disease. A Smith-Petersen nail could not be inserted; so an Austin Moore arthroplasty was performed but dislocation followed. The prosthesis was replaced by a smaller one, with a good result.

Broken leg complicated by popliteal thrombosis with ischaemic contracture of the calf—*Mr Gayton* showed a patient with fracture of both bones of the lower leg, who developed popliteal thrombosis with Volkmann's contracture of the calf muscles.

Bone comminution from saw cut—*Mr C. McKellar* (Sydney) showed a patient with a saw cut of the upper end of the humerus with severe destruction of the humeral head. The fragments were fitted together at open operation with reasonable result.

Unreduced dislocation of radius in Monteggia fracture-dislocation and ununited clavicle—*Mr K. Daymond* (Sydney) asked advice on two cases: 1) a girl of nine sustained a Monteggia fracture and was seen six weeks after injury with an unreduced dislocation of the head of the radius and increasing cubitus valgus; and 2) a woman of twenty-two, seen six weeks after fracture of the clavicle, with an unsightly ununited fracture. *Mr H. Barry* did not think anything should be done in the first case, but that the ununited clavicle should be treated with an inlay graft and fixed with a plaster shoulder spica. *Mr G. Kerridge* thought almost the only indication to operate on fractured clavicles was arterial block, but that in this case it was best to excise. *Mr T. King* thought that the dislocated radius would require replacement later but should be treated conservatively at present. He recommended that after open reduction a wire should be driven through the capitulum into the radius to maintain reduction and should be removed after three weeks. *Mr W. Betts* (Adelaide) and *Mr A. McSweeney* mentioned similar cases of Monteggia fractures treated by open reduction. *Mr J. Cloke* and *Mr W. Gayton* advocated early operation on Monteggia fracture.

Myelomatosis—*Mr J. Roarty* (Sydney) showed a woman of fifty-seven with destruction of the upper part of the sixth cervical vertebra with fever and leucocytosis. With immobilisation pain and temperature settled. A sternal puncture revealed plasma cells. She then had radiotherapy. Later a further deposit became evident in the left ilium.

Talipes equinovarus—*Mr A. Dawkins* (Adelaide) showed a patient with talipes equinovarus. At operation he removed the tibialis posterior and the ligament between the navicular and the talus and performed subcutaneous tenotomy of the ligament between the talus and the calcaneum. The result was very good.

The Annual General Meeting was held in Melbourne, Victoria, from October 12 to 16, 1959. The Association was delighted to welcome the following overseas visitors: Mr H. Osmond-Clarke (Great Britain), Mr W. J. Pike (New Zealand) and Dr K. S. Bose (India).

Presidential address—*Mr John Lahz* (Brisbane), the retiring president, delivered the presidential address.

Open fractures of the tibia—*Mr T. Claffey* (Sydney) reviewed a series of 118 open fractures of the tibia admitted to St Vincent's Hospital and treated by two surgeons, one practising primary internal fixation whenever possible and the other not practising it at all. The series comprised seventy cases treated by conservative methods and forty-eight cases treated by primary internal fixation. Comparisons were made under the following five headings: hospital time, wound healing, bone healing, immobilisation time and final result. 1) Hospital time—average stay in hospital: conservative 37·3 days and radical 88 days. 2) Primary wound healing—conservative 91 per cent and radical 65 per cent. Of the 9 per cent infected cases in the conservative group all infections were superficial, without any case of deep infection or osteomyelitis. In the radical group the 35 per cent of infections consisted of 14 per cent superficial skin infections only and 21 per cent deep infections with chronic osteomyelitis. 3) Bone healing—union (not requiring bone grafting) 95 per cent of cases treated conservatively and 82·5 per cent of those treated radically; one tibia in this group is still ununited. Eighteen and a half per cent of the radical cases developed chronic osteomyelitis and no single case in the conservatively treated group developed bone infection. 4) Average period of immobilisation—conservative treatment 5·8 months, and the radical 8·5 months. 5) Final functional result—the best results of radical treatment as regards length, movement, etc., were very good despite slight bossing and minor shortening (a quarter to a half inch).

In the discussion *Mr H. C. Barry* (Sydney) drew attention to the frequency of bone grafting in hospitals where routine plate fixation was practised. *Mr H. Osmond-Clarke* (London) stated that, while conservative treatment was often indicated, there were three definite indications for internal fixation: difficulty in closing the skin, associated skin loss, and associated burns.

Fixation of fractures by plastic adhesives—*Mr B. Bloch* (Sydney) discussed the factors to be considered in any new implant material, the features of the ideal implant and the characteristics of the plastics so far used, namely the epoxy resins and isocyanates. He reviewed the early operative techniques and the evolution of the present technique which is far less destructive to the soft tissues investing the long bone. Finally he referred to the uses of these resins in wider fields, such as rhinoplasty, where it has been used successfully, vascular surgery, where blood vessels have been successfully united in the experimental animal, and its potential use to replace the shafts of the long bone. *Mr A. I. Rhydderch* (Sydney) considered that, whilst the idea held long term promise, the present method of application was too devitalising, accounting for the fractures that were occurring above and below the actual bonding.

Biceps cineplasty—*Mr John Hueston* (Melbourne) presented a film illustrating the technique of biceps cineplasty and the excellent result obtained in several patients. *Mr C. Callow* (Sydney) wondered how long the patients would wear the cineplastic device, several having reverted to shoulder control. *Mr D. Parker* (Hobart), in a review of the amputees throughout Tasmania, had found that long delay in providing the prosthesis and retraining was one of the main causes of failure.

Atypical osteomyelitis simulating bone tumours and other diseases—*Dr K. S. Bose* (Calcutta) discussed the altered picture of osteomyelitis caused by the introduction of antibiotics. He described fifteen cases seen in the Orthopaedic Department of the Medical College of Calcutta in 1957–58 in which the diagnosis was clouded by atypical clinical and radiological appearances. Four cases resembled malignant bone tumour, five cases resembled fibrous dysplasia and six cases resembled disease of bone other than osteomyelitis. *Mr A. L. Webb* (Sydney) stated that the treatment of osteomyelitis was still surgical drainage. *Mr E. F. West* (Adelaide) made a plea for a restriction in the prophylactic use of antibiotics.

Pain in the neck and arm—*Mr H. Osmond-Clarke* (London) delivered a lecture in association with the Victorian Post-Graduate Committee emphasising the symptoms, pathology and differential diagnosis of the cervical disc syndrome.

A photograph of members and guests of the Australian Orthopaedic Association taken during the 1959 meeting in Melbourne. In the front row, *left to right:* Mr A. Hamilton, Mr John Lahz, Mr Laurence MacDonald (President), Mr R. McKellar Hall (President-elect), Mr H. Osmond-Clarke, Mr J. B. Colquhoun and Mr Eric Price.

Tendon and nerve injuries at the wrist and in the palm—*Mr A. Wakefield* (Melbourne), by invitation, emphasised direct primary repair of these structures as distinct from the usual British practice of secondary repair. When both flexor profundus and sublimis were divided the sublimis was excised. A film was shown illustrating the common clinical types and combinations of tendon and nerve injuries at these levels. The results of primary repair were excellent. *Mr W. J. Pike* (Auckland) said that the results illustrated were superbly good and gave all surgeons interested in this field a goal at which to aim.

The low posterior approach to the hip joint—*Mr A. Hodgkinson* (Sydney) described the detailed anatomy and operative technique of this approach, first described by Austin T. Moore. The conditions in which this approach had been used ranged from fresh subcapital fractures in the aged to old failed nailing and osteoarthritis—at ages from fifty-six to ninety-six. Most speakers agreed that this was probably the best routine approach to the hip.

Osteoarthritis of the knee after meniscectomy—*Mr J. Pannell* (Perth) reviewed the late results of meniscectomy. In the main his cases were drawn from a follow-up of servicemen from the Repatriation Department. After sixty-three meniscectomies, thirty-eight knees presented clinical and radiological evidence of osteoarthritis, twenty were symptomless with no radiographic degenerative changes, five had given symptoms of osteoarthritis but with no physical signs and with no radiological evidence to support the diagnosis. *Mr T. Hogg* (Launceston) referred to previously reported series: McAusland recorded 50 per cent with minor symptoms; Wiberg, 36 per cent; Beresford Beer, 33 per cent of knees osteoarthritic in patients under thirty. Most writers believed that the development of osteoarthritis was related to the number of preliminary lockings and effusions. *Mr C. Callow* drew attention to the early osteoarthritic changes, osteophytic lipping and synovial hypertrophy noticed at operation but not visible radiographically. He believed that osteoarthritis would have developed inevitably in many cases with or without meniscectomy. *Mr N. H. Morgan* (Sydney) considered the function of the cartilage to be to prevent invagination of the synovial tissues.

Mr H. C. Barry stressed the causes of wrong diagnosis, particularly subpatellar chondritis; if the operation were followed by persistent effusion the results were worse. He suspected that this swelling was sometimes due to a mild infection. *Mr W. L. Macdonald* (Sydney) considered that the present-day insistence on total removal of the cartilage often led to unnecessary additional trauma.

The orthopaedic aspects of resistant rickets—*Mr C. Murray Maxwell* (Sydney) reviewed twenty patients with resistant rickets admitted to the Royal Alexandra Hospital for Children during fifteen years. He discussed the pathology and disastrous results of prolonged overdosage with vitamin D. By the time the child reached the Orthopaedic Department deformities of the legs were obvious. He advocated osteotomy rather than osteoclasis to secure correction. The osteotomy was curved and secured by plaster-of-Paris immobilisation, no internal fixation being employed. *Mr A. McSweeney* (Brisbane) corrected the deformity of the lower limbs by supracondylar osteotomy of the femur and osteoclasis of the leg up to the age of five. *Mr E. Price* (Melbourne), with experience of eleven cases, had found osteoclasis to be adequate.

Two clinical meetings were held, the first at the Alfred Hospital. *Mr B. Keon-Cohen* presented patients with osteoarthritis of the hip on whom *Mr R. Hooper*, Honorary Neurosurgeon to Royal Melbourne Hospital, had performed spinothalamic tractotomy for relief of pain. When the disease was bilateral tractotomy was only performed on one side and a routine orthopaedic operation on the other hip. Contra-indications were senility and inability to lie prone for the fifty minutes or so necessary for the operation. *Mr A. L. Webb* pointed out that the operation had often failed to relieve pain because of the cortical component of pain. *Mr Osmond-Clarke* had seen Charcot's joints after such procedures.

Rotator cuff tears—*Mr W. Swaney* presented patients in whom, after arthrography, cuff repair had been carried out. *Mr R. Hodgkinson* (Sydney) stressed the relief of pain that could be obtained from division of the coraco-acromial ligament without recourse to acromionectomy. *Mr Osmond-Clarke* warned against removing the acromion in the " high shoulder " and also drew attention to osteotomy of the neck of the scapula, devised by Mr T. T. Stamm for relief of refractory supraspinatus tendinitis.

Ankylosing spondylitis—*Mr Keon-Cohen* showed a patient in whom neck extension had been improved by a new type of halter while lumbar osteotomy was awaited.

Palliative excision of metatarsal heads and necks—*Mr Keon-Cohen* showed patients in whom excision of the head and neck of the metatarsals had relieved the pain of gross claw foot deformity.

Fibrosarcoma of the deltoid—*Mr Emmett Spring* presented a patient treated by complete resection of the deltoid with four years survival.

Bone grafting of pseudarthrosis after supracondylar femoral fracture—*Mr Emmett Spring* showed radiographs of a successful case in a man of 20 stones or more.

Chondroblastoma—chondrosarcoma—*Mr T. King* drew attention to the pathology of tumours that arise in cartilage. He discussed the features of chondroblastoma—often mistaken for sarcoma. This tumour arose between the ages of fourteen and eighteen from embryonic cells in the epiphysial plate. Radiographs showed an osteolytic lesion, later the site of spotty decalcification. The example shown occurred in the femoral neck. It was treated by curettage and searing of the cavity. Chondrosarcoma arose from normal cartilage cells. He presented a case of a man of thirty-three who had undergone hindquarter amputation. *Mr J. Grant* presented a case of chondroblastoma.

Fracture-dislocation of the fourth lumbar vertebra on the fifth—*Mr J. Grant* presented a patient treated by open reduction.

Irreducible postero-lateral dislocation of the knee—*Mr Brendon Dooley* had carried out open reduction to remove the mechanical block formed by the invaginated capsule.

Late deterioration of a tuberculous knee treated by antibiotics—*Mr J. Gayton* presented a patient with tuberculosis of the knee shown in 1952 with a very good immediate result from antibiotics but later requiring arthrodesis.

Arthrodesis of the shoulder for a partial brachial plexus lesion—*Mr J. Gayton* showed a patient on whom he had performed this operation after myelographic proof of avulsion of the plexus.

Fracture of the femur due to myeloma—*Mr J. Gayton* showed a patient treated by open reduction and Küntscher nailing.

Extreme hypertrophic bone reaction after medullary nailing—*Mr E. Angliss* showed a patient after fracture of the femur.

The second clinical meeting was held at the Orthopaedic Section of the Royal Children's Hospital, Frankston.

Discitis—*Mr J. Critchley* presented three young children with destruction of the lumbar discs apparently due to staphylococcal infection rather than the classical tuberculous infection. They had been treated with a Bradford frame and antibiotics. No biopsy had been done. *Mr McSweeney* had met similar cases in Brisbane and had proved by biopsy that they were staphylococcal; they responded to the appropriate antibiotic.

Bilateral osteochondritis dissecans—*Mr J. B. Colquhoun* showed a boy of ten years treated by immobilisation; most speakers favoured conservative treatment. *Mr H. Osmond-Clarke* believed that the condition healed spontaneously in those under ten years of age. In older subjects surgery was often necessary.

Congenital dislocation of the hip—*Mr Peter Williams* showed: 1) a girl of eleven and a half first seen six years before with stiffness of both hips after prolonged traction, and he described the successive steps taken to give a good gait. 2) A girl, now aged five, who presented first at fourteen months with congenital subluxation. Treatment had consisted of immobilisation, plaster and, later, reduction osteotomy. *Mr H. Osmond-Clarke* and *Mr A. Hamilton* (Sydney) both favoured open reduction if traction in increasing abduction failed to give satisfactory reduction. *Mr L. Bonnin* (Adelaide) drew attention to the importance of using traction rather than forcible manipulation in preventing changes of Legg-Calvé-Perthes disease.

Calf recession—*Mr W. Doig* showed two patients with spastic equinus deformities of the leg treated by calf recession. *Mr D. Parker* reported that in some overseas clinics calf recession was the established procedure.

Flexor tenotomy in claw and hammer toe deformity—*Mr Doig* showed several children who had undergone long flexor tenotomy for claw toe and tenotomy of the short flexor for hammer toe.

Aneurysmal bone cyst of right humerus—*Mr B. Dooley* showed a child of seven who first presented with a pathological fracture through the cyst. Biopsy had been succeeded by irradiation. In the discussion most speakers drew attention to the very real possibility of irradiation sarcoma after treatment for a benign condition. *Mr A. L. Webb* also pointed out deformities he had encountered due to irradiation damage to the epiphyses.

Non-specific arthritis of the left elbow—*Mr Dooley* presented a child of fourteen with a painful swollen elbow in which biopsy revealed early pannus formation together with hypertrophied synovium. All other investigations were negative. Opinions varied between early manifestations of rheumatoid arthritis and non-specific synovitis.

Fractured odontoid process with anterior dislocation—*Mr E. Price* showed a child of four in whom the original deformity had recurred after removal of the plaster-of-Paris. The dislocation was reduced and stabilised by a tibial graft between the atlas and the axis, and wire fixation. *Mr H. Osmond-Clarke* quoted the opinion of Sir Russell Brain that unstable fracture-dislocations of the cervical spine should be stabilised routinely to prevent later long tract involvement.

Multiple congenital deformities—*Mr Price* showed a patient who had bilateral congenital anterior dislocation of the knees together with bilateral congenital dislocation of the hip and arthrogryposis of the feet. The knee dislocations were reduced at seven months after lengthening of the quadriceps. Several speakers had secured reduction by traction alone without resorting to open reduction.

Tendon transfer for poliomyelitic paralyses—*Mr J. Murley* showed a patient in whom the intact tibialis posterior had been transplanted through the interosseous membrane to the cuboid to relieve a drop foot. The patient shown presented his only success in six attempts. *Mr L. Bonnin* considered the operation sound and effective. He had had patients with overaction and preferred to anchor the tendon to the mid-line. To ensure success the foot must be put up with the tendon under firm tension. Mr Murley also showed a patient in whom the extensor digitorum longus had been successfully transplanted to the navicular bone to restore foot balance and prevent deformity.

At the session on October 16, 1959, held at St Vincent's Hospital, radiographs and slides were shown. *Mr G. Colvin* (Sydney) presented an example of synovioma of the lower forearm. *Mr W. Pike* demonstrated a fracture of the pelvis complicated by the development of gas gangrene and also the result of excision of the infarct in Volkmann's contracture. *Mr E. Spring* showed slides illustrating bilateral congenital absence of the radius. *Mr F. Stonham* showed gunshot wound of the meniscus and fusion of the subtalar and ankle joint. *Mr W. Fargie* (Geelong) showed a fracture of the neck of the scapula entering the glenoid with displacement that warranted open reduction. *Mr A. Hodgkinson* showed the pattern of the intramedullary rod he had devised for the treatment of tibial

fractures and exhibited radiographs of several patients treated with this type of nail. *Mr K. Daymond* (Sydney) showed an example of progressive destruction of the upper femoral epiphysis of which the etiology had not yet been determined.

At this meeting the First Annual Golf Match was played. A Stableford Handicap was contested at the Peninsular Country Golf Club. The winner, Mr R. White (Adelaide), received the Colquhoun Trophy, donated by Mr J. Colquhoun, past president of the Association.

FRANCE

HONOUR TO BRITISH SURGEON

We learn with pleasure that the President of the British Orthopaedic Association, Mr H. J. Seddon, was admitted on November 7, 1959, " Doctor Honoris Causa of the University of Grenoble."

BRAZIL

BRAZILIAN SOCIETY FOR SURGERY OF THE HAND

At a recent meeting in Rio, orthopaedic and plastic surgeons combined to found the Brazilian Society for Surgery of the Hand. The first officers of the new Society are Dr Danilo C. Gonçalves (President); Dr Lauro Abreu (Vice-President); and Dr Henrique Bulcão (Secretary). Members of the Executive Committee are Professor Godoy Moreira, Dr Osvaldo Campos, Professor Caio Amaral, Dr Alipio Pernet and Dr Arcelino Bitar.

ANNOUNCEMENTS

BRITISH ORTHOPAEDIC ASSOCIATION

AUTUMN MEETING, 1960

The Autumn Meeting will be held in Leeds and Harrogate from October 28 to 29, 1960, and will be preceded by an Instructional Course on October 27. Those who wish to submit papers for possible inclusion in the programme are reminded that they should submit précis of about 400 words to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2, by June 30 *at the latest*.

CLOSING DATE FOR RECEIPT OF PAPERS OFFERED FOR SCIENTIFIC MEETINGS; ALTERATION OF CONSTITUTION AND RULES

At a meeting of Fellows of the Association in Glasgow on April 8, 1960, it was resolved that paragraph 13 (*b*) of the Constitution and Rules be amended to read as follows: " A Fellow, Member or Associate wishing to present a communication shall furnish the Honorary Secretary with an abstract at least four months before the date of the meeting."

LOVELACE CLINIC, NEW MEXICO

U.S.A.: The Lovelace Clinic, situated in the South West, is expanding its staff of fifty-two physicians. Applications for full-time appointment are invited from qualified specialists in the field of orthopaedics. Opportunities for research are available. Conditions of appointment and detailed information available from the Board of Governors, Lovelace Clinic, Albuquerque, New Mexico.

CORRESPONDENCE AND PRELIMINARY COMMUNICATIONS

AMPUTATION OF ALL TOES

From A. W. FOWLER, Bridgend, Glamorganshire, Wales

To the Editor of the *Journal of Bone and Joint Surgery*:

SIR,

M. Flint and R. Sweetnam in their article " Amputation of All Toes " (*Journal of Bone and Joint Surgery*, **42–B**, 90) state that I advised removal of the bases of the proximal phalanges, refashioning of the metatarsal heads and excision of the painful callus under the prominent metatarsal heads. This is a misleading account of the forefoot reconstruction I described (*Journal of Bone and Joint Surgery*, **41–B**, 507). I advised removal of the proximal *halves* of the proximal phalanges and indicated that more or less may need to be excised in order to correct the clawing deformity. I did not advise removal of the painful callus, but excised an ellipse of skin from the plantar surface of the foot behind the metatarsal heads in order to reposition the metatarsal weight-bearing pad beneath the refashioned metatarsal heads.

The authors state that amputation is advised by many surgeons because there is no value in preserving stiff deformed functionless toes. Forefoot reconstruction preserves the toes, but it converts them into mobile and reasonably shaped digits which retain the important function of fillers of the end of the shoe.

I do not wish to condemn amputation of toes; there may be cases where extreme deformity warrants it. However, when a non-mutilating alternative is possible, we should be prepared to offer it. It is certainly easier to recommend straightening the toes than to persuade the patients to have them cut off.

Whatever operation is used its success will usually depend on adequate trimming of the metatarsal heads. I think that Flint and Sweetnam should have laid more emphasis on the importance of this. Failure to remove enough bone from the metatarsal heads is the most likely cause of the less satisfactory results in some of their rheumatoid patients.

Yours truly,

A. W. FOWLER

We should like to apologise to Mr Fowler for any misleading remarks contained in our necessarily brief description of his excellent method of forefoot reconstruction. We quite agree that trimming of the metatarsal heads is an important step in amputation of all the toes and, indeed, thought we had made this clear in our paper. We feel that both amputation and reconstruction have a place in the surgery of the crippled forefoot and careful selection should produce good results from both.

M. FLINT
R. SWEETNAM

Book Reviews

Lectures on the Interpretation of Pain in Orthopaedic Practice. By Arthur STEINDLER, M.D., (Hon.) F.R.C.S.(Eng.), F.A.C.S., (Hon.) F.I.C.S., Professor Emeritus, Orthopaedic Surgery, State University of Iowa Medical School, Iowa City, Iowa. With Anatomical Dissections by Dr Rodolfo OSENTINO, La Plata, Argentina. 10¼×7 in. Pp. xvii+733, with many figures. Index. 1959. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications Ltd. Price £7, 8s.

This volume comes on the heels of its author's death. It is particularly sad to know that we shall no longer have the opportunity of reviewing works from this master. Others more capable of commenting upon the character of Dr Steindler have already done so; especially Mr H. J. Seddon in his charming note in a previous number of the Journal (**41–B**, 850). No one had a more profound or extensive knowledge of orthopaedic literature than Dr Steindler. His own contributions will cause his name to live with the greatest leaders of the past. His influence will remain among the many surgeons for whom he was a teacher; including the great number who did not have the privilege of working with him personally. He emphasised the importance of careful follow-up studies of surgical results and, as is well known, his *Operative Orthopaedics* was unique in giving statistical information, from his clinic, of the various technical procedures described. In other works he handed back his analytical studies of the literature, and all of them were more than compendiums of extracts. He illuminated everything by his philosophy and practical experience. The present work is a monumental example, for, based upon a study of pain, we have a review of almost every aspect of orthopaedics. His voracious reading and recording is to be seen in the more than one thousand references, which include the names of at least as many authors. One was pleased to see again a statement remembered from an earlier work: There is in medicine, he says, "a natural law, that any single manifestation, subjective or objective, has behind it a multiplicity of organic causes, just as any single pathological event is bound to project itself into a number of different clinical manifestations." It is this feature that lends such excitement to the analytical problems of clinical medicine, and Dr Steindler was always a stimulating guide along these diverging and converging pathways. This volume must be available for students (old and young) in every orthopaedic unit.—Norman CAPENER.

Handbuch der Orthopädie. Herausgegeben von Prof. Dr G. HOHMANN, emer. Direktor der Orthopädischen Universitäts-Poliklinik und Orthopädischen Klinik München; Prof. Dr M. HACKENBROCH, Direktor der Orthopädischen Universitätsklinik Köln; und Prof. Dr K. LINDEMANN, Direktor der Orthopädischen Universitätsklinik Heidelberg-Schlierbach. In vier bänden. Band III: Spezielle Orthopädie: Obere Extremität. 10½×8 in. Pp. xix+659, with 424 figures. 1959. Stuttgart: Georg Thieme Verlag. Price DM 128.

This is the third volume of the massive contribution by German orthopaedic surgeons, the first volume of which appeared in 1957 and the second in 1958, both reviewed in this Journal. Though only about half the size of its predecessors, the present volume follows their pattern. Twelve authors deal thoroughly with congenital, developmental, ischaemic, infective, traumatic, degenerative and neoplastic conditions of the upper extremities. The chapter on congenital and developmental disorders, including recurrent dislocation of the shoulder and written by Dr S. Weil, is particularly interesting. Traumatic lesions of the elbow joint are also well presented by Dr P. F. Matzen in a didactic way, and excellently illustrated. But other chapters also are worth looking into, because they give an up-to-date account of the present views of German orthopaedic surgeons. The bibliography continues to be widely selective even if, as is to be expected and desired, the German literature provides the large majority of references. The editing and printing remain good in spite of one or two trivial misprints, which do not detract from the quality of the contributions and of their presentation.—J. TRUETA.

Clinical Prosthetics for Physicians and Therapists. A Handbook of Clinical Practices Relat d to Artificial Limbs. By Miles H. ANDERSON, Ed.D., Director, Prosthetics Education Project, S hool of Medicine, University of California, Los Angeles; Charles O. BECHTOL, M.D., Profes r of Surgery (Orthopaedics), Department of Surgery, School of Medicine, University of Calif rnia, Los Angeles; and Raymond E. SOLLARS, Associate Director, Prosthetics Education P ject, School of Medicine, University of California, Los Angeles. 11½×9½ in. Pp. x+393, with ıany figures. Index. 1959. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Bla well Scientific Publications Ltd. Toronto: The Ryerson Press. Price 84s.

This excellent work opens with a short section on prescribing an artificial limb, a carefully pl nned exercise in which assistance is sought from the limb fitter and physiotherapist. The remainder f the book is devoted to compliance with these prescriptions, the testing of the prostheses to re uired standards, and training in the use of the limb.

" Book One " covers in great detail the needs after loss of the upper limb at various vels. Suspension, control of joints and of terminal device, be it hook or hand, alternative equipmen and adaptation of the motor car are presented clearly and concisely with the aid of numerous s mple illustrations. Training in the control of and, later, in the use of the various prostheses is partic larly well outlined; the equipment needed is fully listed; and such details as how the armless man ca put on his double prosthesis and so retain his independence are explained with considerable thoroug ness. Special sections are devoted to the problems presented by the child amputee and the double am utee. By the space devoted to it, the biceps cineplastic stump would appear to be favoured, but cinep astic procedures to other muscles are not mentioned and one may conclude are not favoured.

" Book Two " confines itself to the needs of the above-knee amputee and is designed to bring to the surgeon, the limb fitter and the physiotherapist the most up-to-date knowledge on the lower limb prosthesis and on locomotion. Full consideration is given to the physiology and mechanics of normal gait and the gait of the amputee.

Amputation surgery is not dealt with, but, in this connection, the statement is made that, in the lower limb, surgeons should " save all length possible at any level above the musculo-tendinous juncture of the gastrocnemius," implying the abandonment of former " sites of election " in favour of the longest stump above the mid-calf. The move in this direction in the last two decades seems now to be complete: undoubtedly, the longer the stump the better the control, and modern prosthetic technique, devices and materials should enable the limb fitter to accept all these less familiar stumps with good grace if not with pleasure. The treatment of the stump is very fully covered, including a good section on peripheral stump pain, but we are referred to another work from the University of California for help with patients who " suffer from obscure and intractable conditions which in most cases have defied excellent medical care of many years standing "!

The wooden socket of quadrilateral section is much favoured, with suction suspension whenever possible. For a new amputee the plug fit socket is accepted only if he fails to become adapted to the quadrilateral socket with suction suspension; the socket is then enlarged and a stump sock used with pelvic suspension. One would doubt the advisability of this programme for the thin elderly patient after amputation for gangrene; it is he who, in this country, seems inevitably to require the plug fit socket. There is an excellent and detailed description of the construction of the socket, its alignment on the adjustable leg, and the transfer of this alignment to the permanent prosthesis by means of the alignment duplicating jig. All the components of the above-knee prosthesis are fully dealt with, including an assessment of different types. Finally, there is a section on training in the use of the limb in the various circumstances of modern life.

An increasing tendency is evident to prescribe the U.C. quadrilateral type suction socket—a wooden socket of quadrilateral section with high anterior and lateral brims and critical adductor-tendon-to-ischial-tuberosity dimensions. This appears to be a modification of the socket used so widely and with such success in Germany in 1945, and one cannot help feeling that conservatism in this country may still deny this advance to some young people with amputation above the knee.

This volume is so very readable with its numerous and excellent illustrations of all types that it almost makes one wish that the specialist, the limb-fitting surgeon, did not intervene between one's patient and his prosthesis! The book is to be recommended first to the limb-fitting surgeons, who have to face the difficulties in this country of central manufacture in what is becoming more and more a tailor made fit, and secondly to the orthopaedic surgeons, often guilty of insufficient interest and co-operation in the later management of their amputation cases. There is a fund of information for *all* those involved in training in the use of an artificial limb and, in particular, for the physiotherapist. But this volume must also find its way into the libraries of all those concerns manufacturing artificial limbs, as it contains valuable information to all who attempt to serve the limbless.—A. L. EYRE-BROOK.

A Textbook of Surgical Physiology. By R. Ainslie Jamieson, M.B., F.R.C.S.Ed., Surgeon, Vale of Leven Hospital, Alexandria, Dunbartonshire; and Andrew W. Kay, M.D., Ch.M., F.R.C.S.Ed., F.R.F.P.S.G., Professor of Surgery, University of Sheffield. 10×7 in. Pp. vii+623, with 186 figures. Index. 1959. Edinburgh and London: E. & S. Livingstone Ltd. Price 55s.

The development of surgery in the last twenty years has moved away from anatomical and technical modes of thought to become very much dependent on advances in physiology, biochemistry and experimental pathology. These advances have helped surgeons to a better understanding of disease processes and have pointed the way to improvement in methods of treatment. The need for a book giving a clear exposition of what is rightly termed surgical physiology has long been felt. This book goes a long way towards meeting that need. The authors begin with four chapters dealing with general aspects of the body's reaction to abnormal stimuli—the healing of wounds, the effects of radiation, maintenance of fluid balance and metabolic response to trauma. Succeeding sections deal separately with the various systems of the body, covering in each case normal physiology and alterations induced by disease. Orthopaedic surgeons will naturally be most interested in the introductory chapters and in the sections on vessels, nerves and bone, but they will find much interesting and relevant matter in the descriptions of regions unfamiliar to them. The exposition is throughout concise and clear, and the text is well supported by good illustrations and numerous references. As would be expected, the approach to the subject is predominantly a clinical one, and it is the combination of the clinical with the physiological viewpoint which gives the book its great practical value. It is perhaps inevitable that in attempting to cover the whole immense subject in a book of this size the authors have had to restrict somewhat the material included. For instance, the orthopaedic surgeon will feel the lack of a section on the physiology and patho-physiology of joints; the plastic surgeon may require a chapter on the skin; and both may regret the lack of a separate section on modern experimental methods. Even so, the book as it stands is a very valuable contribution and should be of great assistance to both general and specialist surgeons. The authors are to be congratulated on the way in which they have tackled their formidable task. In their preface they show themselves to be well aware of the difficulty of that task and readily admit that there may be omissions. It is hoped that they will find it possible to include additional material in later editions of what is likely to become a standard work.—George Bonney.

Neuropathology. By J. G. Greenfield, M.D., F.R.C.P., LL.D., Consulting Pathologist, National Hospital for Nervous Diseases, London; W. Blackwood, M.B., Ch.B., F.R.C.S.E., M.R.C.P.E., Pathologist, National Hospital for Nervous Diseases, London; W. H. McMenemey, M.A., D.M., F.R.C.P., Pathologist, Maida Vale Hospital for Nervous Diseases, London; A. Meyer, M.D., Emeritus Professor of Neuropathology (Institute of Psychiatry), University of London; and R. M. Norman, M.D., M.R.C.P., D.P.M., Neuropathologist, Burden Mental Research Department, Frenchay Hospital, Bristol. 10×7½ in. Pp. viii+640, with 369 figures. Index. 1958. London: Edward Arnold (Publishers) Ltd. Price £5, 5s.

British neuropathology has suffered its greatest loss with the death of the senior author and editor of this book. Ever since the first world war Dr Godwin Greenfield had kept British neuropathology in the forefront of medical advance, and much of this book reflects his great knowledge of such problems and his attitude to his subject. Trained in the classical methods of Nissl, Alzheimer, Weigert and Cajal he applied these assiduously to the solution of the problems of neurology and probably obtained as much knowledge of the disease of the nervous system as these methods and the light microscope would permit. The chapters on general pathology of the nerve cell and neuroglia, infectious diseases of the central nervous system, traumatic lesions of the central and peripheral nervous systems, demyelinating diseases, system degenerations of the cerebellum, brain stem and spinal cord, diseases of the lower motor and sensory neurones, and lesions of the nervous system associated with diseases or malformations of the cranium and spinal column are all contributed by Greenfield. In them we can trace his attitude to the subject—the meticulous descriptions of histological detail, the accuracy of topography. Yet in his general philosophical outlook one may criticise the attempt to separate the theses of general pathology from those of neuropathology. "This is largely inevitable in so far as it deals with quite different tissues." So does the kidney differ from the liver, the heart from the lungs, and muscle from bone. The development of histochemical techniques may well render the study of the viscera as complicated as that of the nervous system. Dr Greenfield's thesis is that of the pure morbid anatomist and histologist and his work here is at the highest level. His chapter on the general pathology of the cells of the nervous system is unrivalled as a description

of the histological changes seen, but one might have wished for a more biological approach for more emphasis on pathogenesis, for more discussion, out of the wisdom of his experience, of the difficulties of interpretation.

Professor W. Blackwood writes of vascular diseases and the nervous system. He deals with the various syndromes caused by disease of the branches of the circle of Willis, and discusses the disease processes to which the cerebral arteries are susceptible. In a volume of this size one might have wished, however, for a more detailed description of the manifold degenerative processes which are found in the deep penetrating vessels—processes which are quite unlike those found in other viscera. With the increasing percentage of aged patients in the population the pathology of vascular disease of the brain is of ever increasing importance. There is no mention of the cortical or pial arteriosclerosis occasionally responsible for mental disturbance.

Professor A. Meyer has contributed chapters on anoxias, intoxication and metabolic disorders, epilepsy and psychoses of obscure pathology. These are difficult problems in pathology and no British neuropathologist is better qualified to deal with them. Dr R. M. Norman is responsible for the chapter on malformation of the nervous system, birth injury and diseases of early life. Here there is still a great lack of knowledge of the fundamental processes involved, but Dr Norman's illustrations from his remarkable collection of cases add much to our knowledge of the extent of the problem. Dr W. H. McMenemey contributes the chapter on the dementias and progressive diseases of the basal ganglia. These are difficult subjects but the author has given a useful synthesis of the literature. Once again, however, there is no accurate description of arteriolosclerotic dementia which is quite distinct from the arteriosclerotic atrophies.

This book is a compendium of neuropathological knowledge, and for long it will remain in the standard reference book. Pathologists and neuropathologists will find it of essential value in all their neurological problems. Yet one feels that Dr Godwin Greenfield was worthy of a greater monument. Indeed, it is regrettable that he was not the sole author—though this is not in any way to disparage his collaborators. But one would have liked to see the theme of his life-work permeating the whole book, to have avoided the patchiness which multiple authorship entails, and to have been better able to appreciate his philosophy of pathology. It is a book worthy of criticism.—J. Henry BIGGART.

Klinische Röntgendiagnostik Chirurgischer Erkrankungen. In Zwei Bänden. Band I: Röntgendiagnostische Darstellungsmethoden und Klinische Röntgendiagnostik Chirurgischer Erkrankungen der Inneren Organe. By Heinz VIETEN, A.O. Professor Direktor des Institutes und der Klinik für Medizinische Strahlenkunde Düsseldorf; mit einem Beitrag von Dr H. Dettmar, Apl. Professor Leiter der Urologischen Abteilung der Chirurgischen Klinik Düsseldorf. 11 × 8½ in. Pp. xx + 627, with 1,032 illustrations in 698 figures. Band II: Klinische Röntgendiagnostik Chirurgischer Erkrankungen des Skeletes. By Dr Hans OBERDALHOFF, Apl. Professor Chefarzt der Chirurgischen Abteilung der Städtischen Krankenanstalten Mannheim; and Dr Hermann KARCHER, Apl. Professor Chefarzt der Chirurgischen Abteilung des St Marien-Krankenhauses A. Main. 11 × 8½ in. Pp. xvi + 423, with 865 illustrations in 524 figures. Index. 1959. Berlin, Göttingen and Heidelberg: Springer-Verlag. Price DM 398.

Dr Johnson said: " Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it." This publication of two volumes on the radiological aspects of surgical diseases, usually inadequately dealt with in the ordinary text-books on radiology, therefore should deserve a place on the radiologist's and surgeon's bookshelf. The book's aim is to supply the answers which the surgeon expects from the radiologist, and, on the other hand, it gives the surgeon an indication of the scope and limitations of radiological procedures requiring surgical treatment. As the authors point out, the subject of surgical radiology requires some limitations, and they have therefore omitted the radiology of neurosurgical diseases which, in their opinion, is too specialised for this type of text-book. A further difficulty in writing a book of this kind is that digressions into the medical field have to be made, if only for differential diagnosis.

The main criticism is that, once a subject is limited to one particular aspect, such as surgical radiology, it is regrettable that not enough of it is provided to be of sufficient use for the radiologist or surgeon who seeks information on borderline subjects in these two specialities. Some of the discussions on the radiological aspects of surgical conditions are sketchy and incomplete. Aortography for renal diseases, for example, is dismissed in six lines of small print, advocating it, in the reviewer's opinion, with too much caution. Like many other radiological procedures, aortography for urological conditions is not harmless, and the advantages and disadvantages have to be weighed up carefully by the surgeon and the radiologist. However, there can be little doubt about its value in selected cases, and it has become an accepted procedure in many hospitals on both sides of the Atlantic. No mention is made of retrograde femoral aortography.

The second volume deals with diseases of the skeleton. It is a competent and well-balanced text-book, with excellent illustrations of common and rare bone conditions. The chapters on diseases of the spine, and particularly on lumbar disc lesions, are based on the extensive work of Schmorl and are in the tradition of many other good radiological text-books on bone diseases, such as those by Schmorl, Junghanns and Liechti. However, in a book on radiology of surgical conditions, one would like to have read more about the post-operative radiological appearances, because an operation, after all, represents only one major incident in a sequence of events. Not enough mention is made for a book of this kind of the appearances of the bones after grafting, nailing of the femoral neck, arthrodesis, or arthroplasty. This criticism does not imply that, apart from good specialised monographs, better text-books are to be found in the Anglo-Saxon countries.

The volumes are well produced on superb paper, and have all the outstanding characteristics of German text-books of this kind, including a price of about £34 for the two volumes. Any radiological book that aims at narrowing the gap between radiology, surgery and orthopaedics meets a well-felt need and the appreciation of this work is tinged with disappointment that its aim has not been fully achieved. It may well be that a future edition will add further emphasis on the surgical and orthopaedic aspects of diagnostic radiology, and so may find its deserved place on our bookshelves.—Henry W. Gillespie.

Surgery of the Foot. By Henri L. DuVries, M.D., Clinical Instructor in Surgery, Chicago Medical School; Attending Surgeon, Columbus Hospital, Mother Cabrini Hospital and Frank Cuneo Hospital; Chairman, Department of Surgery, Illinois College of Chiropody and Foot Surgery, Chicago. Foreword by Karl A. Meyer, M.D. Introduction by Edward L. Compere, M.D. 10×7 in. Pp. 494, with 403 figures. 1959. London: Henry Kimpton. Price 93s. 6d.

This book is a product of the Chicago school of surgery and is written by one who has devoted thirty years to the study of the structure and disabilities of the human foot. From the first page he stands out as the enthusiastic leader of a crusade for better teaching of the surgery of the foot. The book is an all-embracing work of reference: nothing seems to have been left out. A list of thirty-one pathological conditions of the nail, twenty-one of which begin with the prefix "onycho . . .", may appear complete though not particularly helpful, but exemplifies the methodical mind of the author. There is a good deal of repetition, operative details often being given in the text as well as in diagrams. These, throughout, are excellent, and I was impressed by the simple method of showing essential anatomical points.

It is perhaps odd that more space has not been devoted to common deformities which we find so difficult to treat. I found it disappointing that there are only three pages on the etiology and treatment of congenital talipes and very little guidance in the management of older children with relapse of this condition. Other points that surprised me were the application of tourniquets to the mid-calf, the dosage of a local anaesthetic given as 1 minim of a 1 : 1000 solution in 10 millilitres (surely a mixed terminology), the use of silver nitrate for cauterising granulation tissue. To summarise—it is a pity that so much space has been devoted to short sections inserted merely for the sake of completeness and conveying little useful information. The same may be said of certain operations which are described in detail only to be rejected.

Having said these things, words of praise are not to be forgotten, and I have read this book from cover to cover with much interest and profit. The chapter on static deformities and the section on callosities of the sole are particularly helpful. Anyone who is concerned with the surgery of the foot should read this work, the production of which is beyond reproach.—H. L.-C. Wood.

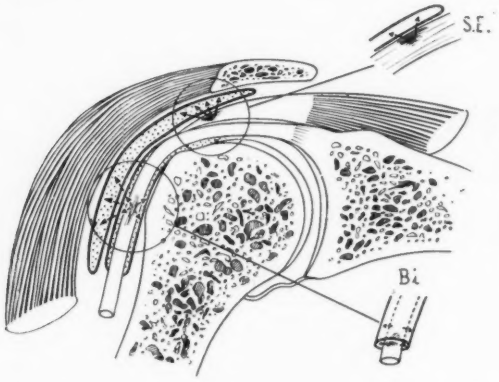
Der Plattfuss. Klinik, Pathologie konservative und operative Behandlung. By Prof. Dr K. Niederecker, o. ö. Professor der Orthopädie an der Universität Würzburg Direktor der orthopädischen Klinik König-Ludwig-Haus. 9½×7 in. Pp. xii+368, with 344 Darunter 20 Farbigen Abbildungen und 15 Tabellen. 1959. Stuttgart: Ferdinand Enke Verlag. Price DM 89.

This work comes from Würzburg, "The cradle of German orthopaedics." Its author is the present holder of the chair of orthopaedics in that beautiful city and also is the President of the German Orthopaedic Society. Early in the book it is remarked that in ancient medical literature much is to be found upon the treatment of club foot but nothing about flat foot, which the author regards as a disease of modern civilisation and for which our unphysiological footwear has much to answer. That a work of over 360 pages should be devoted to this subject seems to us remarkable, because flat foot is but one element of the problem of the static and developmental disorders of the foot.

Apart from the congenital flat foot due to a vertical talus (broken flat foot—*knickplattfuss* the paralytic valgus deformities, spastic pes valgus and arthritic deformities, we in Great Britai feel that flat feet, so long as they are mobile and have good muscle control, are relatively unimp tant compared with the large amount of disability due to such forefoot conditions as hallux valg and metatarsalgia. Certainly in this field most European and North American surgeons must viev with some anxiety the great volume of trouble being provided for the future in the disgraceful sh for women, now so fashionable. In this volume the presentation of the valgus foot in all its asp ts is thorough and there is a good review of the literature, particularly in relation to operative me ods; it is also illuminated by the author's original contributions and his attractive philosophy. It well produced and gives a valuable outline of present day German ideas and practice.—Norman CA NER.

L'Epaule en Pratique Rhumatologique. By S. De SÈZE, A. RYCKEWAERT and M. MAITRE. T vail du Centre de rhumatologie Viggo-Petersen de l'Hôpital Lariboisière (Paris). $9\frac{1}{2} \times 7\frac{1}{4}$ in. P 167, with 208 figures. 1959. Paris: Masson et Cie, Éditeurs. Price 3,800 fr.

This is an excellent comprehensive book on lesions of the shoulder which should be read all orthopaedic surgeons in the original. The quality of the illustrations deserves special praise: the are many drawings of beautiful clarity, and the reproductions of radiographs leave nothing to be d red. In addition, the text is well subdivided so that with 208 illustrations in 167 pages it makes an asily readable book.



← FIG. 33.

Schéma destiné à montrer qu'*une lésion tendineuse*, aussi bien du biceps *(Bi)* que du sus-épineux *(S. E.)*, peut aisément diffuser aux formations séreuses voisines, donnant lieu à *une tendino-synovite* ou à *une tendino-bursite*.

The authors rightly devote the first chapter (and a third of the book) to the consideration of " periarthritis " of the shoulder. The anatomical and physiological peculiarities of the shoulder are considered in relation to the known pathological data. Three clinical types are described, the painful arc of movement, the acute painful shoulder with movement much restricted by pain and muscle spasm, and the frozen shoulder limited by mechanical causes more than by pain. The classical view of the special vulnerability of the tendons of supraspinatus and long head of biceps is shown to be only part of the truth; nor is it a simple matter of extending inflammation to serous bursae analogous with peritonitis. Certainly there is ample evidence from clinical examination, from arthrography and from operative inspection that the lesion in a frozen shoulder is a process of adhesive capsulitis with contracture and not due to subdeltoid adhesions. Periarthritis is also considered in relation to the " shoulder-arm " syndrome with diverse etiological factors such as cervical spondylosis, coronary thrombosis, hemiplegia, Parkinson's disease, pulmonary infections and even visceral lesions. In treatment the authors could well have considered the general management more closely in relation to the natural history of the disease. Too much emphasis is put upon medicinal and injection therapy, and the place of controlled exercises and manipulation under anaesthesia is hardly mentioned.

Chapter 2 is devoted to infective arthritis, and the different types of tuberculous pathology are well illustrated in radiographs. Excision of the lesion is preferred to arthrodesis of the shoulder, and good active mobility is claimed if the resection does not have to be extensive.

The remainder of the book is full of interest. There is a brief discussion of rheumatic disease, gout, osteoarthritis and neurological arthropathy, and the final section, on osseous pathology, includes the rarities such as echinococcus infection, epiphysial dysplasias, Brailsford-Morquio disease and melorheostosis, together with a section on avascular necrosis and tumours.—G. Blundell JONES.

Aplasia and Hypoplasia of the Radius. Studies on 64 Cases and on Epiphyseal Transplantation in Rabbits with the Imitated Defect. By Henrik V. A. HEIKEL. 9×6 in. Pp. 155, with 65 figures and 19 tables. 1959. Copenhagen: Ejnar Munksgaard. Acta Orthopaedica Scandinavica, Supplement No. 39. Price Da. kr. 28.00.

This monograph reports an extensive analysis of 424 case records relating to aplasia of the radius, collected from the literature, together with a clinical investigation of forty-seven patients, radiographic analysis of an additional seventeen cases, and the results of dissection of seven limbs with aplasia of the radius of varying degrees. Cases are grouped into the categories of total and partial aplasia, and hypoplasia of the radius. The operative treatment of thirty-two limbs is described, and it is concluded that a method of treatment aiming at arthrodesis is justified from a cosmetic viewpoint only, and should be confined to unilateral cases with normal or only slightly reduced function in the other hand. Two patients were treated by transplantation of the proximal part of the fibula at the age of six months. Experimental removal of the radius in rabbits produced a deformity like that of aplasia of the radius in man. In four animals transplantation of the proximal part of the fibula to the radial bed prevented marked radial abduction in the radiocarpal joint; the transplant fused with the ulna despite the absence of internal fixation, but the degree of ulnar curvature was not affected. The longitudinal growth of the ulna in aplasia of the radius is little more than half the normal. In animal experiments the fibular graft retains, at the most, half its normal power of growth. Although the method must be finally assessed, it presents theoretical possibilities of a successful result from a fibular transplant.—R. G. HARRISON.

The Sacroiliac Joint in the Light of Anatomical Roentgenological and Clinical Studies. By Kauko A. SOLONEN. 9¼×6¼ in. Pp. 127, with 47 figures and 9 tables. 1957. Copenhagen: Ejnar Munksgaard. Acta Orthopaedica Scandinavica, Supplement Number 27. Price Da. kr. 32.00.

The first part of the investigation deals with the anatomy of the sacro-iliac joint. Unfortunately, only thirty specimens were studied, and it was very difficult, therefore, for the author to add any new concepts. However, the anatomical investigations supported the thesis that the sacrum acts as a keystone, wedged in a downward direction. He confirmed the observation that movement in the sacro-iliac joint takes place around two axes, namely a transverse axis, passing through the body of the second sacral vertebra, and a sagittal axis, passing through the mid point of the symphysis pubis. The author's studies on the range of movements confirmed that it is very small. He did not have the opportunity of studying it at various ages. He found that, on the average, the amplitude of movement around the transverse axis was about 4 degrees, and that the amplitude of movement around the sagittal axis varied between 3 and 19 degrees.

On the clinical aspects of sacro-iliac disease, the author observed that our present radiological techniques do not demonstrate the joint adequately, but he was unable to suggest any particular projections for use in the future. It is interesting that, out of 6,895 patients suffering from low back pain, the diagnosis of sacro-iliac disease was made in only 241. Among these 241 patients there were eight examples of osteitis condensans ilii and sixty-seven examples of infections of the sacro-iliac joint; that is to say, there were only 166 patients in whom a diagnosis of a mechanical disorder of the sacro-iliac joint was made.

Unfortunately, no experimental investigation was carried out to establish the pain pattern of sacro-iliac disorders. The diagnosis, therefore, was dependent on somewhat arbitrary criteria, and many of the symptoms and signs ascribed by the author to sacro-iliac insufficiency could well have been presented by a lumbo-sacral disorder; for example, it was stated that a patient with sacro-iliac lesion was able to bend forward more readily when seated than when standing, a phenomenon also observed in lumbo-sacral disorders. In several patients a new diagnosis was made on subsequent examinations. In one instance the diagnosis was changed from sacro-iliac strain to a haematoma of the gluteal muscle, and in yet another case the diagnosis changed to osteoarthritis of the hip. These diagnoses are so divergent as to cast some doubt on other examples of supposedly sacro-iliac strain. Of the thirteen patients treated by arthrodesis, one subsequently required surgical treatment of a prolapsed disc. Possibly the symptoms were due to disc degeneration from the beginning and settled down on the prolonged bed rest required after the sacro-iliac fusion. This section of the monograph makes it clearly apparent that the symptoms and signs which can be fairly ascribed to sacro-iliac disorders should be carefully assessed, and that there is need for experimental work to establish the clinical picture that can be expected to accompany disorders of the sacro-iliac joint.—Ian MACNAB.

The Human Spine in Health and Disease. Anatomicopathologic Studies by Georg SCHMORL (+19 ?), M.D.; Clinicoradiologic Aspects by Herbert JUNGHANNS, M.D. The First American Edition. ranslated and edited by Stefan P. WILK, M.D., and Lowell S. GOIN, M.D. 11½×8 in. Pp. xii- ?85, with 419 figures. Index. 1959. New York and London: Grune & Stratton. Price $21.00.

From time to time an American edition appears of some Continental classic, and we us share the benefit of a translation into English. This has now happened with the great work on th spine by Schmorl and Junghanns, the fourth (1957) edition of which was reviewed in this Journal (1 7, 39-B, 607). The editors have taken sufficient liberties with the German text and terminology to nake for pleasant reading, and the book has been printed in Germany on the same paper as the Germ. editions so that nothing has been lost of the magnificent quality of the illustrations.—T. J. FAIRBA

Antibiotics in Medicine. Scientific Editor: Lawrence P. GARROD, with eighteen other co ibutors. British Medical Bulletin, Volume 16, Number 1. January 1960. 11¼×8¾ in. Pp. xvii ?8, with figures, diagrams and tables. 1960. London: The British Council. Price £1.

Professor Garrod edits this bulletin of fifteen articles by eighteen experts which aims " provide the reader with well-ascertained information on which he can base his own opinion." The or opaedic surgeon will find many of these articles so lucid and so practical that he will tend to use it as a eference book. He may do so with confidence, but it would be a pity if he did no more than consult its aluable tables. Some of the views expressed here are still controversial, but clinicians have an op ortunity of seeing how far their own opinions conform to the facts in this rapidly enlarging subject. Garrod and Scowen discuss the principles of therapeutics, Lacey the rationale and management of c mbined therapy, and Crofton the chemotherapy of tuberculosis. These articles on clinical use, and hose by Dunlop on the dangers of antibiotic treatment and by Lowbury on bacterial resistance, should be regarded as " essential reading " by all who prescribe antibiotics.—C. H. LACK.

J.-M. Charcot 1825–1893: His Life—His Work. By Georges GUILLAIN, M.D., Membre de l'Institut, Membre de L'Académie de Médicine. Edited and translated by Pearce BAILEY, Ph.D., M.D., Director, National Institute of Neurological Diseases and Blindness; Membre Honoraire à Titre Étranger de la Société Française de Neurologie. 8½×6 in. Pp. xvi+202, with 9 plates. Index. 1959. London: Pitman Medical Publishing Co. Ltd. Price 50s.

Turmoil and crisis is almost the natural state of France. The nineteenth century was one of lasting conflict between the revolutionary tradition, which had set Europe on fire at its start, and the old catholic-legitimist tradition which refused to bow to the changed times. Corruption of all types was rampant. The century saw three major revolutions, the overthrow of the first and second empires and the overwhelming, catastrophic defeat of 1870, with a four-month siege of Paris and a civil war in 1871. Among all this disaster French literature flourished, but medicine did not, the leadership in almost all branches passing to Germany. The great exception was neurology, for modern neurology was born in nineteenth-century France and, despite everything, it flourished.

Jean-Martin Charcot (1825–1893) occupied a position in the history of neurology comparable with that of Robert Jones in orthopaedics. He, more than any other man, was the founder of the modern school. He created the greatest neurological clinic in the world at the Saltpêtrière, in a building originally founded by Louis XIII to serve as a gunpowder store. His contributions to general medicine were of first-rate importance; he was an artist of merit, a pioneer of psychiatry and a medical historian. His pupils included Marie, Déjerine, Babinski, Freud and scores of others of world renown.

It is astonishing to realise that this is Charcot's first biography and that until 1955, when the French edition appeared, we had to rely on obituary notices and short biographical articles for the story of his life. Even his statue was impermanent; the Germans melted it down in 1942. Professor Guillain, who ultimately remedied this lack of a biography, was one of Charcot's successors in the chair of neurology at the Saltpêtrière. He never knew Charcot personally, but he was a pupil of the great man's earliest disciples and is, of course, himself a neurologist of international fame.

The book is divided into two sections, the first dealing with Charcot's life and its circumstances, the second with his work. Both sections are short, and Dr Pearce Bailey's translation reads well. The first section succeeds in bringing the great man to life; the second is perhaps a little fulsome. Even Charcot's scientific work can receive a too glowing assessment (it is certainly not true that he discovered disseminated sclerosis), but that is a minor criticism. The orthopaedic surgeon is reminded that neuropathic joints were described by Charcot as occurring in several diseases, not only in tabes

dorsal[illegible], and there is reproduced a most interesting letter in which Sir James Paget politely denies their e[illegible]istence, as well as that of pathological fractures in tabes, because they had never been seen by Hunte[illegible] and other famous collectors of museums.

T[illegible]ere are too many footnotes (Dr Bailey could have presumed that his readers would be acquainted with t[illegible]e cities of Perugia and Siena, with words like catechumen and with the name of Mérimée), but th[illegible] standard of translation and editing is high, and the final note on the system of hospital appoi[illegible]ments in France will clear up much confusion in the minds of British and American visitors.

I [illegible]njoyed this book, and I am grateful alike to author and to translator.—D. Ll. GRIFFITHS.

Ein L[illegible]en für die Orthopädie. Erinnerungen von Fritz LANGE. Mit einem Geleitwort von Max LANGE. 9[illegible]×6½ in. Pp. viii+212, with 4 plates. 1959. Stuttgart: Ferdinand Enke Verlag. Price DM 26.

[illegible]ese memoirs of a great orthopaedic pioneer are extremely interesting, for Fritz Lange occupied much [illegible]he same position in the history of German orthopaedics as did Robert Jones in Britain. Fritz Lang[illegible] was born in 1864, and from his home town in Dessau (now in East Germany) he went to school in A[illegible]stadt. His earlier university studies were at Jena and he completed his medical education at Mun[illegible]h, where later he carried out his life's work. It was the great age of German medicine in which the s[illegible]ge was held by people like Pettenkofer, Koch, Madelung, Hoffa, Billroth, von Graefe, Nussbaum. He o[illegible]ed much to the influence of von Hertwig the anatomist, who stirred him particularly by his expo[illegible]tion of the muscular system, to the surgery of which Lange was himself to contribute so notably. Intel[illegible]ctually and physically Lange must have had a great dynamic drive, but he also was sensitive in th[illegible] arts—in music naturally, but also in painting and sculpture (a fine print is included of the Venu[illegible]s of Cyrene). The book tells of his early struggles, his marriage, his journeys. He was for two years an assistant to Madelung at Rostock; then he went to Strassburg where he worked unhappily; thence he went to Vienna to work with Lorenz, whom he found insufficiently self critical; and this at a time when in Germany if one wished to learn orthopaedics it was customary to go to Hoffa at Würzburg, who had gained a great reputation as an organiser. And so back to Munich in 1896 where he began his orthopaedic practice. Almost at once he was told that orthopaedics comprised splint making and plaster bandaging, but that operating was the province of surgeons alone. He was left in no doubt that he would not be allowed to practise both. Marriage the same year was followed by times of hardship. In the first year he earned only 800 marks (about £40 in Victorian money), but in the third year it had increased ten times. During these early days there were many struggles, a notable one being with Hessing, an orthopaedic mechanician who, although a maker of superb appliances, was something of a charlatan who took to himself many of the ideas of Johann Georg Heine (1770–1838) the father of German orthopaedic mechanics. Lange's reputation grew as a man who covered the whole field of orthopaedics based upon precise study—of the background problems (the application of sound principles of splinting and the natural processes of growth and repair); of the value of fresh air, sunlight and water; of skilful surgery at the right time; and of proper follow-up studies and after-care.

One hoped to find out what a man of Lange's stature thought of Kaiser Wilhelm II and Adolf Hitler. He says very little about either, though he clearly had a very poor opinion of the Kaiser. He says a good deal about his own part in the first world war and of his organisation of special hospitals on the western front. It is strange that he makes no reference to Robert Jones whom he must have met after the war: and he misquotes the figures of mortality for compound fractures of the femur in British casualties. Lange, by the form of splintage and plaster that he employed to improve transportation, was able to reduce mortality from 50 per cent to 40 per cent, whereas " the English and French had 90 per cent until the Americans arrived." Actually it was the introduction of the Thomas splint by Robert Jones which reduced British mortality from 80 per cent to 20 per cent, and of course it was the method readily adopted by his American colleagues.

Lange made many contributions to orthopaedics which he describes here—to spinal tuberculosis, flat foot, congenital dislocation of the hip, infantile paralysis and muscle transplantation, war surgery and arm prostheses—as well as being a great organiser and leader: but in his later life he did not like being referred to as the latter, which in German is *Fuhrer*.—Norman CAPENER.

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